Popular Astronomy.

Vol. VI. No. 7. SEPTEMBER, 1898. Whole No. 57.

THE PLACE AND FUNCTION OF ASTRONOMY IN EDUCATION.

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FOR POPULAR ASTRONOMY.

The subject assigned to the writer of this paper is the place and function of astronomy in education, from the grammar-school up through post-graduate courses in the university. Eschewing preliminary remarks, and rhetorical display, we proceed at once to the topic in hand, asking the question "What place has astronomy in grammar-school work?" The extensive development of nature study in recent years affords a foot-hold for astronomy in the grades. The interests of children are chiefly in things which they can handle and touch, and especially in living things. Hence most of nature study is occupied with the consideration of plants and animals. The Sun is interesting to them chiefly in that it causes plants to grow, and is a source of amusement in connec- with mirrors and burning glasses. When the stars are out the children are or should be in. Thus the teacher is handicapped at the start, but if the instruction be given little by little, and spread over a considerable space of time, a good deal may be accomplished.

The chief function of astronomy teaching in the grades should be to induce the young people to look upward, and to become acquainted with the general aspects of the heavenly bodies. It is well to begin with the Moon. Some bright morning when the Moon has passed the full, and is well on toward last quarter, let the teacher gather her brood about her, and point out the Moon in the western sky, encouraging them to make pictures showing its shape. Three or four mornings afterward let the teacher take them out again at the same hour, and ask them to find and draw the Moon. They notice that it has changed both its place and its shape. Let them follow it, as best they can, under the teacher's constant guidance and inspiration for a month. Then some of them may be encouraged to look at it with a spy-glass or strong field-glasses for a few nights, beginning near first quarter. After they have made their observations they will clamor for explanations which have so far been judiciously withheld. Thus they may get a start, and become interested.

Next a set of observations on the seasonal changes of the Sun's

place in the heavens, as indicated by the length of the noon-shadow of some large object on the school-grounds, and also by the shifting position of the setting Sun on the western horizon, may be begun. Along with these may go drawings showing the motion of some brilliant planet like Venus, Mars or Jupiter among the stars from week to week, or occasionally oftener. In making these drawings the children notice the star-groups, and their apparent motions with reference to the horizon. They begin to ask questions about them, and are readily led on to a study of the Great Dipper, the Pole-star, Cassiopeia, and a few other constellations which are especially interesting either because of the brilliancy of individual stars, or because of striking configurations which they contain, such as Orion, Lyra, Cygnus, Pegasus, Scorpio, Canis Major, etc. In this constellation work interest may be kept from flagging by narrations of the mythological stories connected with them, and by explanations concerning the most interesting objects in the constellations. The scholars may well be asked to estimate the colors of the brightest stars, and their relative brilliancies. A reasonable thoroughness of acquaintance with the chief stars of each constellation studied may be assured by occasionally sending the scholars to the black-board to make rapid free-hand drawings of them.

Such work as we have outlined may be done very well during the four grammar grades. While the primary result of this instruction is to establish a habit of watching the sky, and to gain a rudimentary acquaintance with the appearance of the heavens, it will be found that an interest has been awakened in the most ancient and noblest of the physical sciences, the geometric imagination has been cultivated, and there has been a decided mental stirring due to even a very superficial apprehension of the great problems with which astronomers have to deal. Many of the poor and lowly, who are to have no further advantages in the way of education, will thus here receive an uplift and outlook much to be prized where the dull routine of life holds so little of inspiration.

Passing to the high-school we are confronted by a serious difficulty, which cannot well be surmounted. Further study of the subject, unless it be of the most dilettante character, must be postponed. For mathematics, Latin, English, history and biological sciences, the presentation of which requires no special knowledge of mathematics, claim all of a pupil's time. It is true that desultory work on constellation study might be done at any time during the first three years of the high school course, but it is

hardly to be recommended. When the students have come to the fourth year they have usually acquired a sufficient knowledge of algebra, geometry and physics to enable them to study the elements of descriptive astronomy in such a way as to get somewhat of a genuine insight into the subject.

Since most of the scholars have not enjoyed the advantages of such study as we have previously outlined for the grammar grades, and because three years have elapsed since the few who took such work were engaged in it, it is best to begin by observing the heavens, and studying the constellations. If it be possible to devote one or two periods a week to this work, from September to Christmas, it will be well. For thus allowance can be made for cloudy weather, and as the months roll by the student will become accustomed by actual observation to the changes in the positions of the constellations due to the diurnal rotation and the annual revolution of the Earth. He will also gain by his own observation a knowledge of the apparent movements of the Sun, Moon and planets among the stars. It should be impressed upon the class that our knowledge of the heavens has been derived from original independent observations, and that in their humble work they should pattern in this respect after the great masters. No scholar should make a practice of observing with another, or relying upon another's eyes or judgment for any detail of the work. Each should work as if he were an original investigator, striving to discover the apparent celestial motions by his own observations. It will not be possible to carry out this idea strictly. It will be wise occasionally, especially at first, to allow groups of two or three to work together. But as soon as they have gained a little confidence in their own powers, individualism is to be encouraged. The teacher should meet the class at times, preferably on moonless nights, to clear up difficulties, and arouse enthusiasm.

In this sort of work better results are obtained, if the students have no text books. The constellations may be carefully drawn on the blackboard by the teacher, the magnitudes of some typical stars being noted. The students may be required to estimate the magnitudes of other stars, and to find answers to various questions concerning their relative positions, etc., which will compel them to confront the sky continually. In connection with these observations the positions of the equator and ecliptic on the face of the sky will be learned, together with those of the equinoxes and solstices. By means of judicious questions the students may be easily led to study out the positions of the celestial poles and

equator with reference to the horizons of observers in other parts of the Earth's surface, and the apparent diurnal motion of the celestial sphere in these places.

Text-book work may now begin, but the teacher must continually bear in mind the fact that while a certain amount of general information about the heavenly bodies is to be obtained, and this can only be accomplished by an exercise of the memory, yet the study should be made to yield as much of mental discipline as is consistent with the student's meager attainments in mathematics and physics.

Here one may justly criticise some of the elementary text-books on descriptive astronomy. They are often loaded down with details which have no perceptible cultural value to high school pupils. Of what avail is it to be told that Niobium, Neodymium, and Glucinum are found in the Sun? Of what significance is it to the student to read that "the apparent diameter of the planet ranges from 3″.6 at conjunction to 2″.5 at a favorable opposition"? How high is the cultural value of the following sentence taken from one of the latest and most attractive American text-books? "Nearly all the tedious and time-consuming labor of examining the plates was performed by ——, ——, and others." It is certainly well for the teacher to strive to lead each student to observe, and to reflect on the significance of his results. As Huxley has said, "The attempt to convey scientific conceptions, without the appeal to observation, which can alone give such conceptions firmness and reality, appears to me to be in direct antagonism to the fundamental principles of scientific education." Since mathematics is pre-eminently disciplinary, we may now inquire how much of the elementary mathematics of astronomy a high school student may reasonably be expected to consider. As the most obvious practical service which astronomers render to the public is the determination of accurate time it is natural to give the lion's share of attention to time determination and measurement. This subject, when carried into its various ramifications, includes a discussion of the fundamental astronomical instruments, the different sorts of days and years, the seasons, the calendar, precession, aberration, parallax, and refraction. Studies concerning the orbits of the heavenly bodies and their perturbations, must, of necessity, be very limited, if the high school student is to extract any profit from them. It is not difficult to have the scholars perform a few simple optical experiments which will give them fair ideas of the optical principles involved in the construction and use of telescopes.

Collegiate courses in descriptive astronomy are similar to those usually given in high schools, but can be made more thorough, with greater attention to details. The increase of thoroughness is notable in those parts of the subject which call for the application of the principles of physics to astronomical problems, especially those involved in what is popularly called "The New Astronomy." In connection with these courses in descriptive astronomy may go essays and discussions upon the history of astronomy, a subject which is almost entirely neglected in our institutions of learning. It is true of astronomy, as of no other science, that its history is that of the intellectual progress of the race along scientific lines. From the earliest ages, when the untutored gaze of primitive man was charmed by the beauty of the young Moon, down to the present time, when watch towers of the skies are to be found in every civilized land, the proudest achievements of the human mind have been in the science of astronomy. Its votaries point with pride to the long list of famous men who have toiled and suffered for Urania.

Comparatively little is now done in the colleges of our country in the way of giving instruction in the more mathematical phases of astronomy. It is a common opinion that such instruction can be profitably given only after the student has pursued analytical geometry and calculus. These subjects are usually studied in the sophomore and junior years, and the majority of students shun severe mathematical work during the last year or two. At that time there are set before them many alluring electives along literary, historical, philosophic and economic lines, which attract their attention and engage their efforts. However, where it is possible to introduce mathematical astronomy early in the college course, quite a good deal of satisfactory work can be done with no more preparation than the ordinary elementary courses in solid geometry and plane trigonometry. Spherical trigonometry is nevertheless very desirable, even in the most elementary courses. To learn what is possible under such circumstances one may examine Barlow & Bryan's Mathematical Astronomy.

After spherical trigonometry and the elements of solid analytical geometry and of calculus have been mastered, various fields open. Of these perhaps the most inviting is practical astronomy, in case a college has an outfit of small instruments, such as a solar transit, a sextant, a meridian transit, a chronometer or clock, and an equatorial furnished with a position micrometer; a chronograph, though not necessary, is much to be desired. It is well to begin with the solar transit, as its use in establishing a

meridian and determining latitude and time gives a student a real hold upon the systems of coördinates in most common use, and their mutual relations. The determination of time by the meridian transit and the sextant naturally follows. The filar micrometer attached to the equatorial then offers a large field of work. The interest of students in such work is much stimulated, if they are encouraged to make a few asteroid or comet observations, and to publish them. For this, however a fair collection of star catalogues is essential.

When such instruments as we have mentioned are not accessible to the students, their attention may be occupied with the problems of spherical astronomy. The times of rising, setting and meridian passage of the heavenly bodies may be computed, making allowance for parallax and refraction. If a small telescope is available, so that one may test by observation the results of his computations, predictions of occultations, eclipses, and the phenomena of Jupiter's satellites may be made. Many other subjects for computation may be readily found in treatises on spherical and practical astronomy. In exceptional cases, where students evince liking for and a moderate degree of skill in computation, they may be urged to compute ephemerides of comets and asteroids, or orbits of double stars. Occasionally it may be possible to give elementary courses in celestial mechanics to undergraduate students, but there are only a few institutions in the country which are able to do it. We have made no reference to celestial spectroscopy and photography, since only a very few of our schools of higher learning are equipped for giving instruction of value along these lines.

When we enter the field of post-graduate study it at once becomes possible to engage in original research of value as well as to pursue particular branches of the science with some degree of thoroughness. Descriptive astronomy now drops almost entirely out of sight, and attention is confined chiefly to the mathematical phases of the subject. Various phases of celestial mechanics come to the front. Courses are offered not only in the determination of orbits, and in the computation of perturbations, but also in the theories of the attractions and figures of rotating bodies. A student may here get a start in some of the most difficult problems with which the human mind has ever grappled. A few of the universities of our country have observatories which are well equipped, and in which post-graduate students may do valuable original work in various branches of practical astronomy. Such work is usually promptly published in some astronomical peri-

odical, so that a student may have the satisfaction that comes from having made a recognized addition to the sum of scientific knowledge.

Having now shown how the different branches of astronomy are developed in our educational system, we have but to answer briefly the question "What is the educational function of astronomy?" That is, "What educational purposes does it subserve?" Some of these we mention in conclusion.

Astronomy fosters a habit of accurate observation; few people know how to use their eyes; they see "through a glass, darkly;" their visual impressions are distorted by their prepossessions, their feelings are their desires. It imbues the student with the spirit of original investigation, that spirit which takes naught for granted, which attacks questions in a candid, fearless, yet eminently careful manner and seeks only to discover the truth. The geometric imagination, that faculty by which we make mental pictures not only of geometrical concepts, but of actual objects, so that we can study out their mutual relation and the effects of their motions, is especially developed. A spirit of independence is cultivated by practical astronomy; almost the first lesson that a tyro is taught is that he must rely upon himself. The work is such that no one can foretell the exact answer to any problem on which he is engaged; he must depend upon his own powers; many a college student who has been accustomed in his previous mathematics to "work for an answer" feels dismayed and almost hopeless when thrown back upon his own resources by some problem in practical astronomy.

To mathematical study is almost universally given the palm for discipline of the reasoning powers. While pure mathematics justly commands our admiration for the elegance of its processes and the accuracy of its results, it must be conceded that applied mathematics affords more effective exercise of the reason, because in any given practical problem, the conditions affecting the problem must be determined, as well as the effects which the conditions cause. Few subjects demand so intense and prolonged concentration of attention as many problems of astronomy which involve long and laborious computations. In some of these an error in a single figure ruins the results of weeks of labor. To remarkable powers of concentration of attention is to be attributed most of the success of the great scientific leaders whose discoveries have contributed largely to the progress of civilization.

Even descriptive astronomy may be taught in such a way as to have considerable disciplinary value. But besides this it has a

distinct ennobling influence, which is greater than that of any other of its sister sciences. It lifts the mind from its narrow round of daily cares, carries it out beyond its immediate environment, leads it into the infinite depths of the universe, calls it to the contemplation of objects of awe-inspiring grandeur, teaches it the most majestic of laws, binds countless worlds into one harmonious whole, brings light, order and beauty out of apparent chaos, and points with unerring finger to the Master Mind whose we are and whom we serve.

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THE SPECTROSCOPE IN ECLIPSE WORK.

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There is often a fashion in astronomical instruments as well as in things more mundane. Some able observer will work out a form to suit his own purposes, and accomplish much by its use; but no one else at once follows in his steps. His instrument falls then into disuse, but ere long some other astronomer arises who finds the now discredited weapon just what he needs, and it comes into vogue a second time. Of such vicissitudes the "object-glass prism," or as, when employed for photographic registration, it is now commonly called, the "prismatic camera," offers a good example. Used by Fraunhofer in the earliest days of "celestial chemistry," for his grand pioneer work, temporarily revived by Secchi and Respighi, it met with almost total neglect until Pickering applied it to stellar spectrography. Here its magnificent success inaugurated quite a new era in our study of stellar physics. And now most recently of all Lockyer has applied it again to solar eclipse work, and it has proved itself in that connection by far the most powerful of all our weapons of research.

Its simplicity of structure gives it the initial advantage of great economy of light. It has a further enormous advantage over the slit spectroscope in grasping the phenomenon of an eclipse in its entirety; it is not restricted to the exiguous slice included between the jaws of a slit. It escapes the confusion caused in the slit spectrum by diffused and scattered light. It chronicles in minutest detail the distribution over chromosphere, prominences, and corona of the gases represented by the bright lines of the spectrum. It is, indeed, not theoretically suitable for the determination of wave-lengths, but, practically, little uncertainty attaches to its use for this purpose. It is possible, by giving a suit-

able inclination to the plate, to obtain a practically perfect focus throughout the entire range of the spectrum—an impossibility in the slit spectroscope, unless used with an absolutely achromatic light gatherer, as, *e. g.*, a reflector. It has but one important drawback; it does not differentiate between a real irregularity of shape in a prominence and an apparent deformation due to motion in the line of sight.

Whenever, therefore, there is a question of which form of spectroscope is to be used in an eclipse, and circumstances forbid more than one being employed, there can be no question that the prismatic camera has the first claim. The slit spectroscope may well be brought forward as a subsidiary weapon of attack. Displacement work is its specialty; its use in wave-length determination is more direct than the prismatic camera, and in the clearing up of one of the most difficult and delicate of eclipse enquiries,—whether a particular gas exists only at a given height above the Sun, or extends from that height right down to its surface—it is of service for presenting the evidence in a somewhat different form. Employed without a primary telescope or condensing-lens to form an image on the slit—as an integrating spectroscope, that is to say—it is useful as registering not the relative intensity of particular rays, but their relative total light, a most important additional information.

Beside these three forms—the prismatic camera; the slit spectroscope used with a telescope as an analyzer; the slit spectroscope used without a telescope as an integrator—there is a fourth form, an analyzing spectroscope used without a slit, the image of the eclipse being formed in the common focus of the condensing telescope and collimator. This gives a spectrum like that of the prismatic camera in form, and though not so economical of light, and only giving a true focus for a limited time range of rays, has an occasional field of usefulness.

The chief interest of the spectroscopic results from the recent and preceeding eclipses attaches to the spectrum of the "flash," the beautiful phenomenon shown just at the beginning of totality, when the rapidly narrowing strip of continuous spectrum is invaded by a constellation of bright points, which shine for a moment as a crowded series of bright little coloured arcs after the continous spectrum has gone, and disappear in their turn a second and a half or so later. The same phenomenon, but in the opposite order, is seen, of course, at the end of totality.

There is no doubt as to the meaning of this short-lived, but most beautiful spectacle. It represents a region of glowing gases

extending to a height of about 700 miles above the solar surface. That much is clear; the debatable point is the relation of these gases to the dark lines which we find in the spectrum of the solar disk.

Until recently most astronomers have been content to follow the opinion of the first observer of the "flash," Professor Young, who considered that these innumerable bright lines corresponded substantially to the Fraunhofer lines, and were in effect their reversable and the "flash" has often been spoken of in consequence as the spectrum of "the reversing layer."

Lockyer, however, has called this conclusion in question, and gives it as his opinion that there is no "reversing layer" at all in the strict sense of the word, but that the absorption of which the Fraunhofer lines are the evidence takes place at a variety of levels above the solar surface, and that the Fraunhofer spectrum is the integration of the absorption exercised by a great number of distinct strata.

This opinion is intimately connected with his theory that the majority of the terrestrial elements which we recognize in the Sun are dissociated at the temperature of the photosphere. The two rival theories are indicated by him in his 'Chemistry of the Heavens,' Chap. XXII., with admirable clearness. The old view affirms the existence of terrestrial elements in the Sun's atmosphere, and their thinning out in the order of vapour-density as we rise above the surface, all being represented in the lowest strata, which, as the regions where the absorption giving rise to the Fraunhofer lines chiefly takes place, may aptly be called "the reversing layer." Lockyer's hypothesis assumes the terrestrial elements, in the main, to exist only in the higher, cooler regions of the Sun's atmosphere; which atmosphere is not composed of substances which thin out as we recede from the Sun, but "of true strata, like the skin of an onion, each different in composition from the one either above or below," and in the lower strata "we have not elementary substances of high atomic weight, but those constituents of the elementary bodies which can resist the greater heat of these regions."

It is clear that the two views allow of some latitude of definition. No one ever supposed that the whole of the Fraunhofer absorption took place within the 700 miles depth of the "flash" to the absolute exclusion of all other strata. Under both hypotheses, under any hypothesis, the Fraunhofer lines are the integration of the effects of *all* the strata through which we look at the Sun. But the composition of the strata is a different matter; and

the old and Lockyerian theories turn on the question whether the successive strata are simply functions of the "thinning-out" process, or are of actually different composition.

Here comes in the immense value of the negatives of the spectrum of the "flash." They give us clearly and distinctly the spectra of the various regions of the solar atmosphere, the height attained by any bright line being clearly indicated in three distinct ways—by the angular extension of the arc over which it is traced, by the height required in a lunar mountain to cover it, and by the time the Moon's limb takes to blot it out. But the answer to the question, "does this particular line represent a gas existing at this height alone, or one extending from this height right down to the photosphere?" is one which only the most minute and detailed examination of each line will answer, and not by any means always clearly then.

But there is one way in which we can easily distinguish between the two theories. In both the Fraunhofer spectrum is the integration of the absorption of all the strata through which we look at the photosphere. But on the old view the main absorption takes place in the lowest strata; they most nearly correspond to the total effect; they form what may be fairly, if a little inexactly, called the "reversing layer." In Lockyer's view the exactly opposite condition prevails. In the lowest strata we have a few intensely-heated primary gases, by analogy giving, in all probability, spectra of extreme simplicity, and hardly entering into the composition of the Fraunhofer spectrum at all—gases, like helium for which the emission balances the absorption. But in the highest strata we find these primary gases entering into combination with each other to form numerous secondary substances of more complicated spectra, lower temperature, and greater absorption. Just as, on the other hypothesis, the lower we go the nearer we get to a complete representation of the Fraunhofer spectrum, and we find the closest approximation to a "reversing layer" at the base of the solar atmosphere; so on Lockyer's view the higher we go the nearer we get to that complete representation and we find our "reversing layer" at the summit of the solar atmosphere. In Lockyer's own words on the old hypothesis, "the spectrum of the base of the solar atmosphere should most resemble the ordinary Fraunhofer spectrum;" on the new hypothesis, "the spectrum of the base should least resemble the Fraunhofer spectrum."

Of course, though our instrumental limitations oblige us to treat the whole of the 700 miles depth of the "flash" as a unity, it is clear that it must cover a most enormous range of tempera-

ture, pressure, and constitution. We cannot, on either hypothesis, push our way right down to the true basal stratum of the Sun's atmosphere. All we can do, then, with our spectrographs of the "flash," is to ask "Which way does the tendency run?" "Are the lowest strata, so far as we can observe them, most like or least like the Fraunhofer spectrum?" If the first, then the dissociation theory is wrong; if the second, it has established its claim.

There is no question—there can be no question—of obtaining a bright-line spectrum which should correspond to the Fraunhofer spectrum like a positive to a negative. The suggestion that this is the point at issue shows a very crude idea of the conditions of the case. We are obliged, observationally, to treat 700 miles depth of atmosphere at the Sun as an homogeneous integer; but we know it cannot be so in reality. Its lowest seven miles would certainly show much individuality if we could observe their spectrum. And again, we have much to learn about the exact nature of the correspondence between the bright-line spectrum of a gas and of the dark lines which it would show as an absorbing agent. The relative intensities of the dark lines of a given element as seen in the Fraunhofer spectrum show many differences from the relative intensities of the bright lines obtained in our laboratories. This fact has been used as a very sheet-anchor of the dissociation theory, but to resort offhand to such an explanation is to evade enquiry rather than to pursue it. One thing, however, clearly results from the number and character of the splendid spectrographs of the "flash" obtained in the recent eclipse; we are now in a far better position for comparing the spectra of solar and terrestrial substances than we could have been by the study of the Fraunhofer spectrum of the disk itself for years, for we can now bring into comparison the bright line emission spectra of the one with those of the other, uncomplicated by any questions of reversal and absorption.—*The Observatory, Aug., 1898.*

THE PHILOSOPY OF HYPERSPACE.*

SIMON NEWCOMB.

There is a region of mathematical thought which might be called the fairy-land of geometry. The geometer here disports himself in a way which, to the non-mathematical thinker, sug-

* Presidential address delivered before the American Mathematical Society at its fourth annual meeting, December 29, 1897.

gests the wild flight of an unbridled imagination rather than the sober sequence of mathematical demonstration. Imaginative he certainly does become, if we apply this term to every conception which lies outside of our human experience. Yet the results of the hypotheses introduced into this imaginary universe are traced out with all the rigor of geometric demonstration. It is quite fitting that one who finds the infinity of space in which our universe is situated too narrow for his use should, in his imaginative power, outdo the ordinary writer of fairy tales, when he evokes a universe sufficiently extended for his purposes.

The introduction of what is now very generally called hyperspace, especially space of more than three dimensions, into mathematics has proved a stumbling block to more than one able philosopher. The question whether a fourth dimension may possibly exist, and whether it can be legitimately employed for any mathematical purpose, is one on which clear ideas are not universal. I do not, however, confine the term "hyperspace" to space of more than three dimensions. A hypothesis which is simpler in its fundamental basis, and yet seems absurd enough in itself, is that of what is sometimes, improperly I think, called curved space. This also we may call hyperspace, defining the latter in general as space in which the axioms of the Euclidean geometry are not true and complete. Curved space and space of four or more dimensions are completely distinct in their characteristics, and must therefore be treated separately.

The hypothesis of a fourth dimension can be introduced in so simple a way that it should give rise to no question or difficulty whatever. Indeed, the whole conception is so simple that I should hardly deem it necessary to explain the matter to a professional mathematical student. But as we all have to come in contact with the educated men who have not had the time to completely master mathematical conceptions, and yet are interested in the fundamental philosophy of our subject. I have deemed it appropriate to present the question in what seems to me the simplest light.

The student of geometry begins his study with the theory of figures in a plane. In this field he reaches certain conclusions, among them that only one perpendicular can be drawn to a line at a given point, and that only one triangle can be erected with given sides on a given base in a given order. Having constructed this plane geometry, he passes to geometry of three dimensions. Here he enters a region in which some of the propositions of plane geometry cease to be true. An infinity of perpendiculars can now

be drawn to a given line at a given point, and an infinity of triangles can be constructed on a given base with given sides. He has thus considered in succession geometry of two dimensions, and then passes to geometry of three dimensions. Why should he stop there? You reply, perhaps, because there are only three dimensions in actual space. But in making hypotheses we need not limit ourselves to actualities; we can improve our methods of research, and gain clearer conceptions of the actual by passing outside and considering the possible.

For logical purposes there is no limit to the admissibility of hypotheses, provided we consider them purely as hypotheses, and do not teach that they are actual facts of the universe. It is, therefore, perfectly legitimate to inquire what our geometry would be if, instead of being confined to three dimensions, we introduced a fourth. Many curious conclusions follow. When we are confined to a plane a circle completely bounds a region within a plane, so that we cannot pass from the inside to the outside of the circle without intersecting it. Beings conscious only of two dimensions and moving only in two dimensions, and placed inside such a material circle, would find themselves completely imprisoned, with no possibility of getting outside. But give them a third dimension, with the power to move into it, and they simply step over the circle without breaking it. They do not even touch it. Living, as we do, in space of three dimensions, the four walls, pavement and ceiling of a dungeon, confine a person so completely that their is no possibility of escaping without making an opening through the bounding surface. But give us a fourth dimension, with the faculty of moving into it, and we pass completely outside of our three dimensional universe, by a single step, and get outside the dungeons as easily as a man steps over a line drawn on the ground. Were motion in the fourth dimension possible, an object moving in that dimension by the smallest amount would be completely outside of what we recognize as the universe, and would therefore become invisible. It could then be turned around in such a way that on being brought back it would be obverted, or appear as in a looking glass. A man capable of such a motion would come back into our sight similarly obverted, his left side would now be his right, without any change having taken place in the relative positions of the particles of his body. The somerset he would have turned would have completely obverted every atom and molecule of his body without introducing any disturbance into its operations.

This possibility of obversion brings in a curious question con-

cerning the rigor of one of the fundamental propositions in elementary geometry. Euclid proves by superposition that the two triangles in a plane having two angles and the included side equal are equal to each other. In the demonstration it is assumed that the triangles can be made congruent by simply placing one upon the other without taking it out of the plane. From this the conclusion is drawn that the same conclusion holds true if one of the triangles be averted. But in this case they cannot be brought into congruence without taking one of them out of the plane and turning it over. The third dimension is thus assumed in geometry involving only two dimensions.

Now consider the analgous case in space. Two pyramids upon congruent bases may be proved equal by bringing them into congruence with each other. But suppose that they differ only in that one is the obverse of the other, so that they could be brought into congruence only by looking at one of them in a mirror and then placing the other into congruence with the image of the first as seen in the mirror. Would we detract from the rigor of the demonstration by assuming the possibility of such an obversion without changing the volume of the pyramid? With a fourth dimension we should have no detraction from rigor. We would simply obvert the pyramid as we would turn over the triangle.

The question of the fourth dimension as a reality may be considered from two points of view, its conceivability and its possible objective reality. If by conceivability we mean the power of being imaged in the mind it must be admitted that it is absolutely inconceivable. We have no difficulty in forming a visual conception of three lines passing through the same point, each of which is at right angles to the other two. Such is the familiar system of coördinate axes in space. But he who would conceive a fourth dimension must be able to imagine a fourth axis perpendicular to all three of the others. This clearly transcends all possibility even of imagination. The fourth dimension in this sense is certainly inconceivable.

The question of the objective possibility of the fourth dimension is quite a distinct one from that of its conceivability. The latter limitation upon our faculties grows out of the objective fact that we and our ancestors have had no experience of a fourth dimension; that we have always lived in a universe of three dimensions only. But we should not too readily conclude that all being is necessarily confined to these three dimensions. Those who speculate on the possible have taken great pleasure in imagining another universe alongside of our own and yet distinct from it. The

mathematician has shown that there is nothing absurd or contradictory in such a supposition. But when we come to the question of physical fact we must admit that there appears to be no evidence of such a universe. If it exists, none of its agencies intrude into our own universe, at least in the opinion of sober thinkers. The intrusion of spirits from without into our world is a favorite idea among primitive men, but tends to die out with enlightenment and civilization. Yet there is nothing self-contradictory or illogical in the supposition. The fish that swims the ocean experiences objects which, to him, seem to come from outside his universe—steamships for example. If our atmosphere had been opaque to the rays of light from the Sun, or even if it had been so filled with clouds and vapor that we could never see outside of it, we also should have had a similar experience. But we may be said, in a certain sense, to see through the whole of our conceivable space with the aid of our telescopes, and the general tendency of scientific thought at the present time is toward the conclusion that no natural agency of which we can trace the operation originates outside the space into which our telescopes may penetrate. Our universe forms, so to speak, a closed system. This is true apparently even of agencies so subtle as those which give vibrations to ether. If there is any agency which we could imagine to connect us with an outside sphere it is certainly the luminiferous ether. But should this ether enter into a fourth dimension the intensity of light and radiant heat would diminish as the cube of the distance and not as the square. To speak more accurately, radiance emanating from an incadescent body would be entirely lost—would pass completely out of our universe. The fact that it is not lost, and indeed the general theory of the conversation of energy, shows that there is no interchange of energy between our universe and any possible one lying in another dimension of space.

We may regard the limitations of the dimensions of space to three as expressing in a certain way a physical fact. Our conception of space is originally based upon the possibility of motion. The threefold possibility of relative motion can be reduced to a physical fact in this way. Let a point be fixed at one end of a rod, the other end of which is immovably fixed to a wall. The point can then have motion over the surface of a sphere whose center is at the fixed point and whose radius is the length of the rod. Now fix one end of a second rod to another point of plane and bring the two ends of the rods together, and fix the point on both ends; then the point can only move in a circle. Fasten it to

a third point of the plane with a third rod, and it cannot move at all. But if we add a fourth dimension it could move.

The limits of space are for us simply the limits of possible motion of a material body. We can imagine a body coming from any point in three-dimensional space to us, but cannot imagine one coming from outside of such space, until we add a fourth dimension.

Our conclusion is that space of four dimensions, with its resulting possibility of an infinite number of universes alongside of our own, is a perfectly legitimate mathematical hypothesis. We cannot say whether this conception does or does not correspond to any objective reality. What we can say with confidence is that if a fourth dimension exists, our universe and every known agency in it is, by some fundamental law of its being, absolutely confined to three of the dimensions. But we must not carry a conclusion of this sort beyond the limits set by experience. When we say that experience shows that not only our material universe but all known agencies in it are, by a law of their being, incapable of motion in more than three dimensions we must remember that the conclusion applies only to those motions which our senses can perceive, the motions of masses in fact. There is no proof that the molecule may not vibrate in a fourth dimension. There are facts which seem to indicate at least the possibility of molecular motion or change of some sort not expressible in terms of time and three coördinates in space. If we consider those conceptions of mechanics which we derive from visible phenomena to afford a sufficient explanation of molecular action we must admit that, when the position and motion of every atom of a given substance are defined, the chemical properties of that substance are completely determined. If we take two collections of atoms of the same substance, put them together in the same way, and endow them with the same kinds of vibratory motion, we ought, on any mechanical theory of matter, to obtain substances of identical properties. Now, there seems to be reasons which I cannot stop at present to develop that might makes us believe in changes of properties and attributes of substancee not completely explained by molecular changes. That such is the case with vital phenomena can be demonstrated beyond a doubt; that it is the case with chemical phenomena when they approach the vital character seems very probable. Certainly there is some essential difference between that form of molecular motion in which heat is commonly supposed to consist and the motion of masses. Perhaps the most remarkable of these differences consists in the relation of this

motion to the ether. The motion of a mass suffers no resistance by passing through the ether with the highest astronomical velocities. Matter so rare as that of the diffuse comets may move around the Sun with a speed of many miles per second without suffering the smallest resistance from the ether—in a word, without any friction between the matter and the ether. But when the molecules have the motion of heat, that motion, if motion it be, is always communicated to the ether, and is radiated away from the body, which thus becomes cool. Whatever form we attribute to the energy of heat, it is certainly a form which is constantly communicated from matter to the ether by a fundamental law of matter. Consequently, if heat be really a mode of motion, as is now generally supposed by physicists, it follows that there is some essential difference between the character of this motion and the motion of the smallest masses into which matter can practically be divided. The hypothesis of vibration in the fourth dimension merely suggests the possibility that this kind of motion may mark what is essentially different from the motion of masses. Of course, such an hypothesis as this is not to be put forward as a theory. It must be worked out with mathematical rigor, and shown to actually explain phenomena before we assign it to any such rank.

I cannot but fear that some confusion on this subject is caused by the tendency among both geometers and psychologists to talk of space as an entity in itself. As I have already said, a fourth dimension in space is nothing more than the addition of a fourth possibility of motion to material bodies. The laws of space are only laws of relative position. Certain fundamental axioms are derived from experience, not alone individual experience, perhaps, but the experience of the race, giving rise to hereditary conceptions born in the mind and corresponding to the facts of individual experience. A tree confined to one spot, even if it had eyes to see and a brain to think could never have a conception of space. For us the limits of space are simply the limits to which we can suppose a body to move. Hence when space itself is spoken of as having possible curvatures, hills and hollows, it seems to me that this should be regarded only as a curvature, if I may use the term, of the laws of position of material bodies in space. Clifford has set forth, with great acuteness and plausibility, that the minute spaces occupied by the ultimate atoms of matter may, in this respect, have properties different from the larger space which alone makes itself known to our conceptions. If so, we should only regard this as expressive of some different law of motion,

or, since motion is only change of position, of some different law of position among the molecules of bodies.

This consideration leads us to a possible form of space relations distinct from those of our Euclidean geometry, and from the hypothesis of space of more than three dimensions. I refer to what is commonly known as "curved space." The history of this conception is now so well known to mathematicians that I shall mention it only so far as is necessary to bring it to your minds. The question whether Euclid's axiom of parallels is really an independent axiom underivable from the other axioms of geometry, is one which has occupied the attention of mathematicians for centuries. Perhaps the simplest form of this axiom is that through a point in a plane one straight line and no more can be drawn which shall be parallel to a given straight line in the plane. Here we must understand that parallel lines mean those which never meet. The axiom, asserts that through such a point we can draw one line which shall never meet the other line in either direction, but that if we give this one line the slightest motion around the point in the plane it will meet the other in one direction or the opposite. Thus stated, the proposition seems to be an axiom, but it is an axiom that does not grow out of any other axioms or geometry. The question thus arising was attacked by Lobatchevsky in this very conclusive manner. If this axiom is independent of the other axioms of geometry then we should be able to construct a self-consistent geometrical system, in conformity to the other axioms, in which this axiom no longer held. The axiom of parallels may be deviated from in two directions. In the one it is supposed that every two lines in the plane must meet; no line parallel to another can be drawn through the same point in the plane. Deviating in the other direction we have several lines drawn through the point which never meet the given line; they diverge from it as lines on an hyperboloid may diverge.

That such possibilities transcend our ordinary notions of geometrical relations is beyond doubt, but the hypothesis of their possibility is justified by the following analogy. Let us suppose a class of beings whose movements and conceptions were wholly confined to a space of two dimensions as ours are to a space of three dimensions. Let us suppose such beings to live upon or in a plane and to have no conception of space otherwise than as plane extended space. These beings would then have a plane geometry exactly like ours. The axiom of parallels would hold for them as it does for us. But let us suppose that these beings, without actually knowing it, instead of being confined to a plane,

were really confined to the surface of a sphere, a sphere such as our earth, for example. Then, when they extended their motions and observations over regions so great as a large part of the Earth's surface, they would find the axiom of parallels to fail them. Two parallel lines would be only two parallel great circles, and though each were followed in a direction which would seem to be invariable they would be found to meet on opposite sides of the globe. The suggestion growing out of this consideration is: May it not be possible that we live in a space of this sort? Or, to use what seems to me to be the more accurate language: May it not be that two seemingly parallel straight lines continued indefinitely would ultimately meet or diverge? The conceptions arising in this way are certainly very interesting. If the lines would meet it can easily be shown that the total volume of all space is a finite quantity. The sum of the three angles of a triangle extending from star to star would then be greater than the sum of two right angles. Equally legitimate is the hypothesis that it would be less than three right angles, but in this case the total volume of space would still be infinite. Now, this is an hypothesis to be tested by experience. Unfortunately, we cannot triangulate from star to star; our limits are the two extremes of the Earth's orbit. All we can say is that, within those narrow limits, the measures of stellar parallax give no indication that the sum of the angles of a triangle in stellar space differs from two right angles. If our space is elliptical, then, for every point in it—the position of our Sun, for example—there would be, in every direction, an opposite or polar point whose locus is a surface at the greatest possible distance from us. A star in this point would seem to have no parallax. Measures of stellar parallax, photometric determinations and other considerations show conclusively that if there is any such surface it lies far beyond the bounds of our stellar system.

Such are the considerations by which it seems to me that speculations on this subject may legitimately be guided. The wise man is one who admits an infinity of possibilities outside the range of his experience, but who in considering actualities is not decoyed by the temptation to strain the facts of experience in order to make them accord with glittering possibilities. The experience of the race and all the refinements of modern science may be regarded as showing quite conclusively that, within the limits of our experience, there is no motion of material masses in the direction of a fourth dimension, no physical agency which we can assume to have its origin in regions to which matter cannot move,

when it has three degrees of freedom. Claiming this, we must carry the claim only to the limits justified by actual experience. We have no experience of the motion of molecules; therefore we have no right to say that those motions are necessarily confined to three dimensions. Perhaps the phenomena of radiation and electricity may yet be explained by vibration in a fourth dimension. We are justified by experience in saying that the space relations which we gather from observation around us are valid for the greatest distances which separate us from the most distant stars. We have no right to extend the conclusion further than this. We must leave it to our posterity to determine whether, in either way, the hypothesis of hyperspace can be used as an explanation of observed phenomena.

EPHEMERIS OF SATURN'S RINGS.—ASTRONOMICAL PHENOMENA.

J. MORRISON, M. A., M. D., PH. D.

FOR POPULAR ASTRONOMY.

It is now well established that Saturn's rings consist of an immense number of very small satellites each describing its own independent orbit around the planet but subject of course to the disturbing influence of its neighbors. Any point on the inner or outer circumference of the ring, may therefore be regarded as an independent satellite and the circumstances of its apparent motion can be determined by the formulæ investigated in my paper on the Ephemeris of Satellites. See No. 3, Vol. VI, May, 1898.

The elements of the rings are, according to Bessel and Hall as follows:—

ECLIPTIC.

Epoch 1800 Jan. 0.0

$$\lambda' = 166^\circ\ 53'\ 8.9'' + 46.46\,(T - 1800),$$
$$i = 28^\circ\ 10'\ 44.7'' - 0.25\,(T - 1800).$$

EQUATOR.

Epoch 1900 Jan. 0.0

$$\lambda = 127^\circ\ 5'\ 49'' + 138''\,(t - 1901)$$
$$I = 6^\circ\ 57'\ 39'' - 14.5''\,(t - 1901)$$

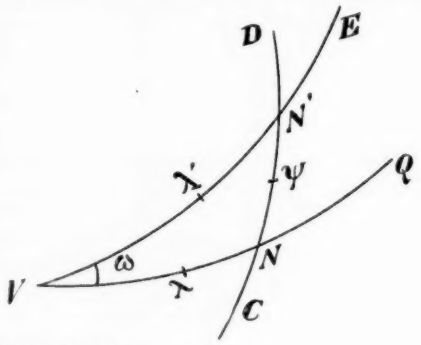
where λ' and λ are the longitudes of the nodes in the Ecliptic and Equator respectively and I and i the inclination. We also have $\psi = 42^\circ\ 15'\ 15'' - 95''\,(t - 1901)$

The elevation of the Earth and Sun above the plane of the rings, is computed by Eq. (226) or (230) using of course the elements referred to the ecliptic in the case of the Sun. The longitude of the Earth counted on the plane of the rings from the ascending node on (1) the equator and (2) the ecliptic is,

$$\begin{aligned} &\text{in the former, evidently} = u_0 + 90^\circ, \text{ and} \\ &\text{in the latter} \qquad\quad = u_0 - \psi + 90^\circ \end{aligned}$$

where u_0 is determined by Eq. (226) and ψ the angular distance between the nodes on the equator and ecliptic and is computed thus:—

Let VQ be an arc of the equator, VE an arc of the ecliptic, V the vernal equinox, CD the intersection of the plane of the rings with the planes of the equator and ecliptic and N and N' the ascending nodes on these planes respectively. Put the angle



$NVN' = \omega$, the obliquity of the ecliptic
$VN = \lambda$, the longitude of the ascending node on the equator
$VN' = \lambda'$, the longitude of the same node on the ecliptic, and
$NN' = \psi$, the required distance.

From the spherical triangle VNN' we have

$$\cos\psi = \cos\lambda\cos\lambda' + \sin\lambda\sin\lambda'\cos\omega$$

Put $a\cos A = \cos\lambda$

$a\sin A = \sin\lambda\cos\omega$

that is $\tan A = \tan\lambda\cos\omega$

then we shall have

$$\cos\psi = a\cos(\lambda' - A) = \frac{\cos\lambda}{\cos A}\cos(\lambda' - A) \qquad (235)$$

The values of λ and λ' are brought forward to the required date by means of their annual variations given in the elements. With the same data we may also compute the values of I and i by the "sine proportion" or better by Delambre's formulæ.

A table containing the values of ψ for a series of years, is found in Professor A. Hall's paper on the Orbits of the Satellites of Saturn in the Washington observations of 1883. The value of p or the inclination of the semi-minor axis of the apparent orbit, to

the declination circle, estimated from the north toward the east, is given by $p_0 - 90$ or by (229). The apparent dimensions of the rings are easily found by means of the distance Δ and the factors given in the ephemeris.

ASTRONOMICAL PHENOMENA.

These are computed for the centre of the Earth and may be divided for convenience into the following classes viz.:

(1) Conjunctions
(2) Oppositions
(3) Quadratures
(4) Perihelion and Aphelion
(5) Nodes
(6) Greatest Heliocentric Latitude.
(7) Stationary Points
(8) Greatest Elongation

The computation of the dates of these phenomena presupposes that a complete ephemeris of the Sun, Moon and planets has been already computed, otherwise the labor would be enormous.

(1) *Conjunctions.*—A mere inspection of the ephemerides of the bodies about to come into conjunction, will give an approximate date at which conjunction will take place. For some two or three hours preceding and following this date, subtract the R. A. of the body which moves most rapidly from the R. A. of the other and set down the difference and form the 1st, 2d, etc., order of differences thus,

Date.	Diff. of R. A.	1st Diff.	2d Diff.	3d Diff.
T_{-2}	$+ a_2$			
		$+ b_2$		
T_{-1}	$+ a_1$		$+ c_1$	
		$+ b_1$		$- d_1$
T_0	$+ a_0$		$- c_2$	
		$- b_0$		$- d_2$
T_1	$- a_1$		$- c_3$	
		$- b_1$		
T_2	$- a_2$			

We have now to find when the quantity in 2d column becomes zero, taking the 1st, 2d, etc., differences into account.

The ordinary interpolation formula is

$$a^{(t)} = a_0 + t\, b_0 + \frac{t(t-1)}{2}\, c_0 + \frac{t\,(t-1)\,(t-\frac{1}{2})}{2\ .\ 3}\, d_0 + \text{etc.} \quad (236)$$

where $c_0 = \frac{1}{2}(c_2 + c_3)$ and $d_0 = -d_2$ in the above notation, and in

the present instance $a^{(t)} = 0$ and t is the unknown quantity.

Developing the formula, neglecting t^2 and solving we have

$$t = \frac{-a_0}{b_0 - \frac{c_0}{2} + \frac{d_0}{12}} \qquad (237)$$

which is sufficiently accurate for this purpose.

(2) and (3) *Oppositions and Quadratures.*—The same formula is applicable, the 12 or 6 hours difference being disregarded.

(4) *Perihelion and Aphelion.*—An inspection of the heliocentric coördinates of a planet will give an approximate date. Tabulate the values of the radius vector or of its logarithm for some two or three days preceding and following this date and proceed to form the 1st, 2d, etc. order of difference as in the case just considered. Formula (236) can then be applied, but in this case $a^{(t)}$ will be a maximum or a minimum. We therefore differentiate and put the differential co-efficient equal to zero, thus

$$\frac{da^{(t)}}{dt} = b_0 + tc_0 - \frac{c_0}{2} - \frac{td_0}{2} + \frac{d_0}{12} + \text{etc} = 0$$

whence

$$t = \frac{-b_0 - \frac{c_0}{2} - \frac{d_0}{12}}{c_0 - \frac{1}{2}d_0}$$

or

$$t = \frac{-2b_0 - c_0}{2c_0}, \text{ if 3d diff. be omitted.} \qquad (238)$$

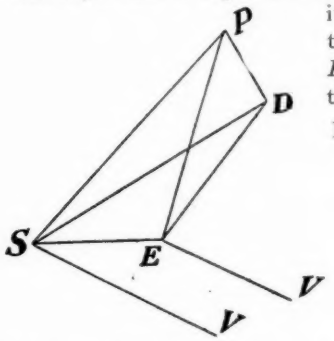
(5) *Passage through the Node.*—At this date the heliocentric latitude will be zero, and the date itself will be easily found by (237).

(6) *Greatest Heliocentric Latitude.*—This occurs when the heliocentric latitude has its maximum value and is found by (238). The latitude is then equal to the inclination of the orbit.

(7) *Stationary Points.*—An inspection of the ephemeris of the planet will show when the R. A. ceases to vary, that is, to increase or decrease and at such times the planet evidently appears stationary. A simple interpation will generally be sufficient for this purpose, but if greater accuracy be required we may employ Eq. (238). In the case of the inferior planets, two tangents can always be drawn from the Earth to their orbits, and when the planet is at these points of tangency it is evidently moving either directly towards or from the Earth and will therefore appear stationary, or to put it more accurately and as it actually is, the straight line joining the Earth and the planet moves

parallel to itself; consequently the planet appears, for a short time, to preserve the same direction in space. The motion of the planet between the stationary points, is of course retrograde. In the case of the superior planets, a tangent cannot be drawn from the Earth to their orbits, nor is it by any means evident that they should have stationary points at all. It will therefore be necessary to show that all planets must retrograde and have two stationary points during a synodic revolution.

Let P, S and E represent the planet, Sun and Earth respectively; draw PD perpendicular to the plane of the ecliptic; join PS, PE, DS and DE and let EV, SV be the direction of the equinox.



Put $l = VSD$, the heliocentric longitude of the planet.
$L = VSE$, the heliocentric longitude of the Earth.
$\lambda = VED$, the geocentric longitude of the planet.
$\alpha = DE$, the planet's curtate distance from the Earth.
$\rho = SD = PS \cos PSD =$ r cos Hel. Lat. the curtate distance of the planet from the Sun and let $SE = 1$, the Earth's orbit being regarded as a circle which is sufficiently accurate for our purpose as we only intend to show that every planet must retrograde and therefore appear stationary.

From the diagram we easily find

$$\rho \cos l - \cos L = a \cos \lambda$$
$$\rho \sin l - \sin L = a \sin \lambda$$

whence
$$\tan \lambda = \frac{\rho \sin l - \sin L}{\rho \cos l - \cos L}$$

Differentiating, ρ being constant, we have

$$\sec^2 \lambda \, d\lambda = \frac{(\rho \cos l - \cos L)(\rho \cos l dl - \cos L dL) + (\rho \sin l - \sin L)(\rho \sin l dl - \sin L dL)}{(\rho \cos l - \cos L)^2}$$

or
$$d\lambda = \frac{[\rho^2 - \rho \cos (L - l)] \, dl + [1 - \rho \cos (L - l)] \, dL}{(\rho \cos l - \cos L)^2 \sec^2 \lambda} \qquad (239)$$

But
$$\frac{dL}{dl} = \frac{\text{Periodic time of the Earth}}{\text{Periodic time of planet}}$$
$$= \frac{\rho^{\frac{3}{2}}}{1}$$

or
$$dL = \rho^{\frac{3}{2}} dl$$

Substituting in the above, reducing and putting for brevity

$$A^2 = \frac{1}{(\rho \cos l - \cos L)^2 \sec^2 \lambda}, \text{ we have}$$

$$d\lambda = A^2 \left(\rho^2 + \rho^{\frac{3}{2}} - (\rho + \rho^{\frac{5}{2}}) \cos (L - l)\right) dl \qquad (240)$$

When the planet is in *apogean s y z y g y*

$L - l = 180°$, $\cos (L - l) = -1$ and (240) becomes

$d\lambda = A^2 \rho (1 + \rho^{\frac{1}{2}}) (1 + \rho) dl$ which is always ***positive*** and therefore the motion is direct.

When the planet is in *perigean s y z y g y*

$L - l = 0$, $\cos (L - l) = 1$ and then we have

$d\lambda = A^2 \rho (1 - \rho^{\frac{1}{2}}) (\rho - 1) dl$ which is always negative whatever be the value of ρ and therefore the geocentric motion is retrograde.

In changing from direct to retrograde as well as from retrograde to direct, $d\lambda$ becomes zero, and then we have

$$\cos (L - l) = \frac{\rho^{\frac{1}{2}} + \rho}{1 + \rho^{\frac{3}{2}}}$$

$$= \frac{1}{\rho^{\frac{1}{2}} + \rho^{-\frac{1}{2}} - 1} \qquad (241)$$

an equation always possible since the second member is always less than unity whether ρ be greater or less than unity, that is to say, *all* planets must retrograde and therefore have stationary points.

If t denotes the interval from *s y z y g y* (conjunction or opposition) to time when the planet is stationary we shall have

$$L - l = (dL \sim dl)\, t$$

or

$$t = \frac{L - l}{dL \sim dl} \qquad (242)$$

therefore the planet's motion appears retrograde while it describes an arc of its orbit equal to $2 \frac{(L - l)\, dl}{dL \sim dl}$, and direct through the remaining position.

If the Earth were at rest we would have

$dL = 0$ and (239) becomes

$$d\lambda = A^2 \left\{\rho^2 - \rho \cos (L - l)\right\} dl$$

which could never become zero for a superior planet, and since

we know from actual observation that these planets do appear stationary at certain times, this result furnishes a proof of the Earth's orbital motion.

The arcs through which the planets retrograde and the times occupied are approximately as follows:

Mercury	8°.5 to 16°.0	and 20 to 24	days
Venus	15°.3 to 16°.5	" 41 to 43	"
Mars	11°.1 to 19°.5	" 62 to 81	"
Jupiter	10°	119	"
Saturn	6°.8	137	"

(8) *Greatest Elongation.*—From the ephemeris we can always obtain an approximate date—in fact it can not be very far from the stationary points. The ephemeris also gives the logarithms of the radii vectores of the Earth and planet and the logarithm of the distance between them, we thus have the three sides of a plane triangle with which to compute the angle at the Earth.

When this is computed for several equidistant dates we can easily determine when it is a maximum by Eq. (238).

With this short and hastily written article the series of papers on the construction of the American Ephemeris and Nautical Almanac has arrived at

THE END.

CURRENT ASTRONOMY.

WM. W. PAYNE.

Leo Brenner, director of the Manora Observatory made observations of Mars during 1897, and from his observations, we gather some opinions concerning the "canals" of Mars that should receive notice. From the cuts published in the *Naturvissenschaftliche Wochenschrift* XIII, No. 14, it is evident that he has seen a considerable number of "canals" and other features of the surface of the planet now well observed and well known by several other astronomers in different countries, notably France, Italy and the United States.

Mr. Brenner thinks that the network of "canals" can not have been made by Nature, because they so much resemble a map of triangulation. All readers who know of the triangulation used in Coast Survey work, and that are employed in the interior of the United States for geographical purposes, will understand clearly what is meant. Amateurs in astronomy also know that triangulation has been used in getting the relative places of the larger

stars of the Pleiades. By the aid of the heliometer, the distances between these stars can be measured very accurately. The object of this work in this group is mainly two-fold: 1st, to learn in time, if these stars are parts of one great system, or stars moving in space independently, and, 2d, from a knowledge of the relative places of the bright stars of the group, occultations of them by Moon may be more useful, for determining the places of the Moon at such times and, finally, a better knowledge of the orbital motion of the Moon.

In regard to this network of "canals" Mr. Brenner says everything leads to the conviction that it is artificial; if so it must have been constructed by the inhabitants of Mars. The difficulty with this explanation has been the great magnitude of such a work. The accompanying frontispiece shows something of the number, length and peculiaries of intersections of them at points called oases. If the planet is 4,500 miles in diameter, is it possible, especially by people like ourselves to carry forward and complete such a tremendous piece of engineering as this? Apparently these great ditches or water courses are twenty to thirty miles wide and thousands of miles long, and the entire surface that we call land is covered with them. If the surface of Mars is very uneven or mountainous such projects would be next thing to impossible. Observers, however, are pretty well agreed that the surface of Mars is not very uneven, certainly not mountainous like the Earth or Moon, probably more like the desert regions of our planet. There is reason to believe that Mars is much older than the Earth if we accept the nebular hypothesis, because the planet is so much smaller than the Earth. If it be remembered that the amount of matter in Mars is only $\frac{1}{7}$ of that of the Earth, and that the density is less than $\frac{3}{4}$ that of the Earth, we have added reasons for thinking that Mars would grow old fast compared with the rate of physical change Earth is making in approaching the condition of a dead world like that of the Moon now. This idea is supported when we think that the Moon is probably much younger in time than Mars, and still so much older in planetary decay. This need not be a wonder when the mass and the density of the three bodies are taken into the account and it is noticed that Mars is but little more than a mean proportional between the Earth and the Moon.

Mr. Brenner suggests that, because Mars is so much older than the Earth in planetary life, it is reasonable to suppose that the mountains on the surface of the former planet would be worn down by the action of the elements in ages of time, the same

way the leveling process is going on over the Earth's surface. This suggestion seems very plausible, and it may be the true explanation of the vast and almost uniform desert tracts that make up the land surface of Mars. However, the analogy does not hold in regard to the Moon. We certainly know that the lunar surface now in the state of fixity, is by far more irregular and mountainous than the surface of the Earth, if we consider the relative sizes of the two bodies. It would scarcely seem that meteorological forces the tidal action and small surface gravity were sufficient, all working together to produce what we suppose is the surface condition of Mars at the present time.

For our present purpose it matters little how the surface of the planet came to be as it is. If those who think that the "canals" are artificial, and form a great system of irrigation are right in their guesses, then the generally even surface of the planet is a most helpful condition for the Marticoli engineers, because they may run these immense water courses as they please, for such obstructions as mountains would never hinder. Possibly but little expense need be incurred in passing from one water level to another, in the system, for the change of elevation would be gradual, and a few locks here and there would be sufficient for all purposes of navigation. To the thoughtful person, it is a wonder how the engineers of the people of Mars could show their skill and the science that must have been growing and advancing for ages longer than anything of the kind known upon this Earth. If Mr. Brenner is right in supposing that they are not "canals" at all, that is, great broad and deep ditches for the flow of water, but simply dikes thrown up to control the flow of the water on the surface generally, like those in use in Holland, or the artificial banks of the lower Mississippi in the United States, then the matter of construction becomes simple and easy, and we wonder only at the extent of the system and the reasons for it. The amount of snow fall in the temperate and polar regions during the Martian winter appears to be great, and the rapid melting of the same during the spring and summer on the planet also seems to bring large quantities of water into the temperate and middle zones. During these seasons the "canals" are plainly visible, and they are more easily observed by the aid of the telescope than at other seasons of the Martian year. Mr. Lowell's book on Mars gives so much good evidence on this point, that the proof of this view seems quite conclusive.

One statement that Mr. Brenner makes is obscure. It is "As to the gemination of the canals, I have arrived at the conclusion

that it does not exist!" We suppose he objects to the name "double canals" for he knows of and speaks of "parallel canals." The fact is some of the canals are parallel, and those that are certainly seen range, in distance apart, from 156 miles to 220*. The time of gemination seems to be different in different canals, and it is hard to find any good reason for this strange fact in regard to them. The Ganges canal is often referred to as an interesting example.

By this dike system, Mr. Brenner would explain other phenomena on the surface of Mars, such as the regions of Libya and Hesperia, those that are very dark or only partially so. The same explanation is applied to the oases and lakes. So that quite all the different phenomena of the planet's surface are included in this new mode of interpretation. As more evidence is found by good planet observers in the future, we shall be better able to say whether or not Mr. Breuner's views in his interesting paper are supported.

Professor G. Frederick Wright, of Oberlin College, has recently written a book on Scientific Aspects of Christian Evidences. Knowing of his scholarly attainments in some lines of research, we had little doubt but that the contents of this new book would have a bearing on astronomical themes. In this we were not disappointed, for the first two chapters are especially noteworthy in this regard. The title of the first chapter is "Limits of Scientific Thought." Attention is called to the way scholars should examine the foundations of a Christian faith and hope. As grand and profound as scientific discoveries have been during the nineteenth century, Professor Wright raises the question whether modern science is not more superficial than it is popularly represented to be. Has the scientist taken strict account of what he has really gained in knowledge during the last century? Has he materially reduced the realm of the unknown in this most active period of scientific investigation? Is it not the conviction of the most learned that scarcely anything has yet been accomplished compared with that which may be known in time to come? So it is thought wise to take stock of our ignorance often, that we do not assume too much in our estimates of what in science is really known. Then, the so-called scientific attitude of mind proper for the inquirer to be in, when he seeks for new truth is of vital importance. There is a state of mind that is open to truth from any reliable source, always ready to be convinced by the weight of evidence. This is a normal condition of mind

* See Lowell's Mars page 190.

and one, we believe, that will have penetration and wield unusual power. But if there are false assumptions with regard to the limits of thought evil consequences will surely follow. Professor Wright quotes * Herbert Spencer as affirming that God is not only unknown to man, but also, that he can not be known except in a negative way. The fault with Spencer is that he is not equally careful in affirming and denying in regard to the limits of knowledge. It is not true that the unknown is unknowable, neither should these states of mind be confounded. Professor Huxley did not make this mistake in defining his position.

In clearing the ground of current misapprehensions concerning the limitations of knowledge Professor Wright discusses our limited knowledge pertaining to the origin of matter, the origin of life, the endless existence of the present order of things, the continuity of nature, the possible immortality of the soul, the existence of evil not inconsistent with the benevolence of God, the unknown capacity of the human mind, and the significance of these negative results. From the announcement of such a series of topics, arranged and presented for such an end in view, one who is at all interested in laying deep and broad foundations for mental acquirements, can not but take careful heed to such thoughts.

But in the second chapter of this book we find things more important that every student should ponder most thoroughly. We have consulted more than one thoughtful scholar to get his impressions of the matter presented, and the replies for substance have been, the matter is very important, it must be read again, before much can be said about it. The title to this chapter is "*The Paradoxes of Science.*" It has to do mainly with the attempted explanations of science regarding the mysteries of existence. The themes considered are, the Newtonian theory of gravitation, the atomic constitution and the mystery of life and of matter. What has really been learned in regard to each of these topics is carefully and fairly presented. It seems to us to be modern science put in characteristically modern garb. It has been subjected to the methods of the higher criticism, and the incisive logic of the author has left of it nothing of the useless or the extravagant. While few love science more than we, none will rejoice more than ourselves to see its dross go, that its enduring beauty only may remain.

* Scientific Aspects of Christian Evidences, page 2.

LIST NO. 8 OF NEBULÆ DISCOVERED AT THE LOWE OBSERVATORY, ECHO MOUNTAIN, CALIFORNIA FOR 1900.

LEWIS SWIFT.

FOR POPULAR ASTRONOMY.

No.	Date.	R. A. h m s	Decl. ° ′ ″	Description.
1	Feb. 22	5 29 20	— 36 28 30	*eeeF. eeS. eee. Eeeedif.* See note.
2	" 14	5 30 8	— 23 24 15	*eF. vS. R.* 8^{m*} *f* 10^{s} in field with 1979.
3	Jan. 31	5 47 40	— 38 22 45	*eeeF. S. cE.* semi-circle of 3*st S. vdif.*
4	Feb. 20	9 31 5	— 11 56 30	*pB. pL. R. 2stnrf.*
5	" 19	9 39 40	— 31 18 35	*eF. S. R. vE** close *nf. pB* nrSp.*
6	Jan. 12	9 45 5	— 32 27 40	*eeeF. pS. vE. bet* below * and 8^{m*} *p. nf* of 2.
7	" 12	9 45 30	— 32 27 45	*eeeF. eeeS. R. D** close *Sf. Sp* of 2.
8	Feb. 19	9 52 40	— 31 47 40	*vF. pS. R.* 8^{m*} *p.*
9	" 15	9 55 25	— 29 10 30	*eeeF. pS. CE, trapezium n* and *nf. D* np. eeedif.*
10	" 14	9 59 25	— 27 4 50	*eeF. L. CE. nB* vnr.* No ⊿ as per 3113.
11	" 15	10 27 30	— 23 32 10	*eeeF. eS. eE.* 8^{m*} close *p. eeedif.*
12	" 15	10 31 30	— 23 34 10	*eF. pS. R. bet* 2 *Dst Sp* and *nf.*
13	" 22	10 32 35	— 10 35 55	*CB. eS.* stellar.
14	" 14	10 33 25	— 26 32 20	*pF. pS. D* nf.* Not one of Sir J. Herschel's 9.
15	Jan. 14	10 58 30	— 15 41 45	*eeF. eeS. lE.* looks at first like a *D**.
16	Feb. 12	11 26 50	— 29 52 40	*vF. pS. R. Sf* of 3717.
17	" 20	11 44 0	— 11 45 40	*eF. CL* 2⊿ with **n* and another *f.*
18	" 20	11 45 25	— 19 1 57	*B. S. eE.* a ray.
19	" 15	12 14 10	— 25 35 20	*pF. vS. R.* 8^{m*} *nrnp.*
20	" 15	12 35 15	— 36 13 20	*pF. vS.* 2 or 3 *vFst* in contact.
21	" 23	12 44 20	— 3 51 25	*eeF. L. eE.* 7^{m*} *S* little *f.*
22	Jan. 31	12 55 0	— 31 43 50	*eeF. pS. R.* 10^{m*} *nrnf.*
23	" 30	13 59 40	— 38 43 40	*eeF. pS. R. bet* 2*st. nr* center of trap.
24	Feb. 22	14 6 50	— 30 3 33	*F pS. R. sevFst* around it.
25	" 22	14 28 20	— 27 7 18	*pB. eS. R.* looks like *D** one nebulous.

NOTES.

No. 1. This is another line nebula much resembling No. 7 list 4. There is a slight bulging in the center but it requires very close scrutiny to see it. They must be either rings or flat disks placed parallel to the line of sight. In field preceding are ½ a dozen stars in form of a segment of a large circle. No bright star near.

No. 14. This is not one of Sir John's Herschel's 9.

Erratum for No. 19 list No. 6, as published in *Astronomical Journal* and perhaps other journals. For decl. — 22 read 32.

New General Catalogue 3145 is an interesting nebula but so near Lambda Hydra as to much obscure it. I made its R. A. for 1860 10^{h} 3^{m} 3^{s} while Herschel makes it 10^{h} 3^{m} 18^{s}. I describe it as *vB. L. vE.* while H. says *F. pLR.* and says nothing about its proximity to Lambda Hydra. I saw no other and our objects are no doubt identical.

THE GROWTH OF WORLDS. II.

W. W. PAYNE.

By the aid of the cut of Ptolemy herewith presented, the reader will better understand the explanation of the cross-staff, to which reference was made in our last number.

CLAUDIUS PTOLEMY.

(OBSERVATIONS BETWEEN 127-171 A. D.)

We know very little of the personal life of Ptolemy, but his influence as a scholar in his time was very marked, unequalled by any before him, and his opinions in regard to the movements of the heavenly bodies were regarded as authority for 1400 years as before mentioned. One reason of the great influence of his views doubtless was due to the fact that he wrote carefully on all astronomical themes which he knew, and published them in a book called the *Almagest*. It is said of this great work that no sub-

stantial addition was made to it during all this long period. The singular omission however, that has been noticed in it, since the sixteenth century, is the lack of all reference to comets. Aristotle and his school held that comets were only exhalations from the Earth existing in the upper atmosphere and never beyond, so that such bodies did not properly belong to astronomy; they were only meteorological in nature. For this reason Ptolemy would not dignify the comet to give notice of it in the *Almagest*. When we know of Ptolemy's knowledge of geometry, trigonometry, of philosophy and of his ingenious notions regarding the motions of the heavenly bodies, it is a wonder that the character of the comet should have passed his attention so easily and erroneously. The weight of Aristotle's opinion was great, but Ptolemy was usually the scholar who thought for himself, as his writings plainly show. However, in this case Ptolemy seems to have adopted the opinion of the great philosopher without even giving a reason for it so far as we know.

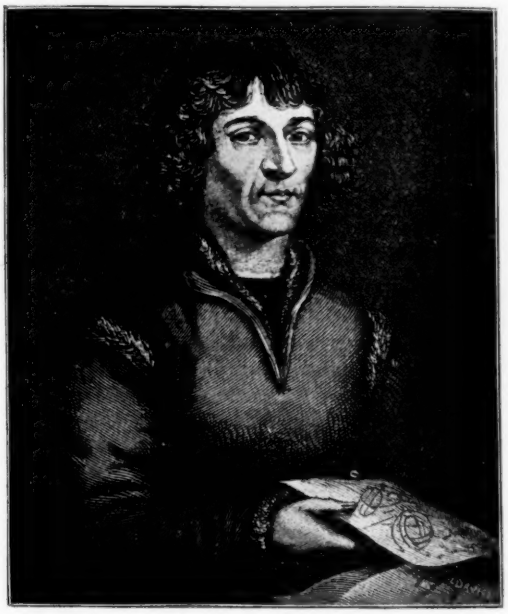
The next name that is great in astronomy, singular in history and a household word in Christendom, is that of Nicolaus Copernicus, Born in Thorn on the Vistula, Feb. 19, 1473, he began his education at home, pursuing his studies most diligently later at the University of Cracow. He first devoted himself to the study of medicine, intending to follow it as a vocation, but his interest in mathematics soon led him into astronomy, although in the meantime he had acquired some skill in the art of painting.

At the age of twenty-seven he gave himself wholly to science, and, as a teacher of mathematics gained some reputation which drew to him the notice of his uncle, a bishop, through whose influence he was appointed to a canonry in the Cathedral of Frauenburg.

This young man of varied gifts then did what is hard generally to do at such a period in life. He left ordinary society and devoted himself unsparingly to the work before him. His theological duties were first, his medical skill was a gratuity to the poor and then part of his time was devoted to the study of astronomy and mathematics. Our cut shows him with geometrical diagrams in hand, apparently in the act of thinking out some knotty problem in the course of his regular studies. His thoughtful face is itself a lesson to ponder. Does it show that his intimate companions were the learned, and that less useful associates were shunned? His biographers say this of him.

But how did Copernicus study astronomy is another important question? It is said that his instruments for the study of the

heavens were very simple. He made holes in the walls of his house, to observe stars as they passed the meridian of his place. He contrived some machinery that showed his inventive genius.



NICOLAUS COPERNICUS.

(1473-1543.)

It was not long before his mind began to grapple with the great questions of astronomy which resulted in discoveries that have made his name immortal.

If Ptolemy's views of the solar system had stood like a rock through the Middle Ages, it is now probable that some had thought and taught differently. Pythagoras the Grecian philosopher (580-500 B. C.) appears to have taught his disciples "that the Sun and not the Earth was the center of the movement" * of the planets, though we have no satisfactory proof that his views had any real scientific basis.

With Copernicus the case was plainly different. By a course of reasoning which convinced those who would listen to him of the

* Ball's Great Astronomer, p. 34.

truth of the two great points of his system of the planets, viz: that the Sun is at the center of the system and that the Earth rotates on its axis once in twenty-four hours. It must ever be a matter of great interest to all readers how Copernicus came to these important conclusions, in view of all the circumstances.

It is not easy to put ourselves in his place and fully grasp his real situation. Ptolemy had studied these two points very carefully, and had decided that the Earth was stationary, as we have before seen, and that fully covered both points in question before the mind of Copernicus. But the latter was not satisfied. The whole course of reasoning was gone over again and again, and finally he reaches exactly the opposite conclusion from that of Ptolemy. The rising and setting of the Sun, and the apparent daily motion of the great celestial sphere, could all be explained equally well if the Earth had a similar daily rotation on its axis. In view of the vast extent of the starry sphere it was more rational to the mind of Copernicus to believe that the Earth should rotate than to think that the whole heavens turned on its axis once in twenty-four hours. Ptolemy had realized the difficulty of supposing the daily rotation of the celestial sphere. He had thought that if the Earth turned on its axis once in twenty-four hours it would cause such terrific winds on the surface as to sweep away everything movable. Copernicus claimed that this would be impossible, and proved that the air would move with it in its daily motion, just as one's "coat goes with him when he is walking the street."

Another thing Ptolemy taught about the celestial sphere which was not satisfactory to Copernicus. It was the claim that all the stars were attached to this great material sphere, and hence, all equally distant from a common center within occupied by the Earth. There is, of course, nothing impossible in this view of the structure of the starry heavens. The stars might have been located in this way as well as any other and Ptolemy with his means of observation could not tell the difference, as long as the distances of all of them was so very great compared with the distances of the planets which he had studied so carefully. Because he could not observe anything in the twenty-four years he worked, that would give him some clue to the varying distances of the stars, he assumed that the apparent fixity of relation and uniform daily motion to be the true motion of all the stars, hence they were all equally far away. This view did not satisfy Copernicus. Ptolemy seems to have depended on the test of observation as a last court of appeal in important cases of doubt. Not

so to the same extent with Copernicus. The reason for things which he could not verify in this way were sometimes powerful with him. The grasp of mind which sees almost intuitively the true relation of things in quick and accurate judgment was a characteristic of his mental work. To our mind this is the marked difference between these two great men.

ASTRONOMICAL MYTHS—THE FLAT EARTH.

THOS. LINDSAY.

For Popular Astronomy.

"How can the Earth be round? I have sailed all over it, and everywhere found it as flat as a flounder." Such was the dictum of an old sailor who prided himself on his keenness of observation, and who would allow of no qualifications but one,—"barring the hills."

If the flat-Earth idea were simply a silly notion it would not be worth writing about. We might dismiss it with a good natured laugh, or we might become testy over it and echo the opinion of a friend of mine, "the man who declares that the Earth is flat—that man would—would steal!" At all events we might dismiss it, if it were only silly; but there is more than that in the idea. Why is it so old? Why are some otherwise intelligent citizens imbued with it? For it is really the oldest of all myths; and my friend was only speaking in a Pickwickian sense. Some explanation seems wanting, and in the investigation we may be led deep into philosophy, of a certain kind.

Professor Payne tells us that there are "Earth Flatteners" under the shadow of Carleton College. We are not going to see a little place like Northfield get ahead of us and for every one produced there we can show his "ditto" around Toronto. And it was during a conversation with one of these friends that I seemed to gather something of the truth about this curious myth.

The first impression made upon me was that the E. F. is absolutely sincere, always so, and further, he looks upon his opponents with a genuine feeling of commiseration. I can never forget the words, the tone, the look, of one with whom I had had pleasant intercourse on other topics when he asked me "Do you, too, believe the Earth is round?" He would have made a fortune as Julius Cæsar, but he was only the editor of a country newspaper. I was the heretic, and quite incapable of putting the contra ques-

tion to him in the same spirit, simply because it was a matter of little moment to me; the depth of feeling was on his side. It was this set me a-thinking. He was also a "near-Sun" man, and very strong on that point. It was sarcasm, not pathos, in his tone when he asked me, after looking at the solar disc in the telescope, "Do you mean to tell me that the Sun is a hundred million miles away?" I felt like whacking him on the head then.

Well, let us try to understand this thing seriously. The first man who had leisure to think, time he could spare from grubbing after food, must have looked on the face of his surroundings and instantly gathered the idea that he lived on a plane. No doubt he saw round things about him, cocoanuts for instance; and he would have the idea of a circular dome, the vault of the skies above him; and a circular figure, the one bounding his vision. But there was nothing in these to give him the idea of a round Earth. Then he would hunt about for other quarters occasionally and would have always the old sailor's experience, however he might express it. And so he grew up and left descendants who advanced little by little in knowledge, until they built great cities, engaged in commerce, sailed over what was to them a mighty sea, established laws, and wrote sublime poetry. And all this while, without a breath of heresy, the world was a circular plane and it might be possible to tumble over the edge of it. Were all these people silly? Surely not. Do they not serve us yet as models in some departments of human knowledge? We have abolished slavery, but leaving that out how much further are we ahead in the science of all sciences, sociology? Our commercial affairs are a little more complicated, due to expansion, but the merchants of Babylon and Nineveh kept their accounts pretty much as we do; and has not some bright genius with his card index system gone back to the days when they used to scribble a customer's account on a mud cake and bake it? And what mariner today would undertake to navigate even Lake Ontario without a compass and chart, as the Phoenician sailors navigated the Great Sea. Upon what are our common laws founded? How much does our literature owe to the writings of the ancients? Ask this of some enthusiast in Homer. Who would have dared contradict the Father of Poetry when he drew Ocean encircling the great plane of the Earth? No one, for one and all were as positive as the old sailor or my friend the editor that the world was as flat as a flounder. But they must have lacked something; the ancient mind must have been in some respects distinctly different from the modern, or if not that, some attributes must have lain

dormant. The last I think was the case; what had not yet been aroused was, the faculty of understanding geometrical figures. And down through all these long ages this opaqueness of mind has existed, revealing itself occasionally by virtue of that mysterious principle, atavism, in the intellectuality of the modern E. F.

Some of our ideas are the result of an unbroken series of occurrences, similar generally, while varying in detail, and this we call evolution. But it seems to me that the science of geometry was not evolved, rather sprang into existence in a day. How else are we to account for what is certainly given us as an historical fact that Pythagoras, after his Egyptian education, discovered for himself the fundamental proposition of geometry, which today bears his name? Professor Cajori gives us an absolute proof that the mathematicians of Egypt took the product of half the base and one of the sides for the area of the triangle. Now we would not demand that every little Egyptian street Arab should know how to determine areas, but one would expect that those who were engaged in laying out land and settling taxes on the same would have learned, as a result of experience, that there was one simple rule for all triangles. But it seems they did not; in fact they were not aware that there was any one truth common to all triangles, except that they all had three sides! To me there seems no getting away from the conclusion that the mind of Pythagoras was opened suddenly, by an act of Providence if you will, to see that the rightangled triangle of sides 3, 4, 5, possessed its remarkable property by virtue of the angle, not of the proportions of the sides. This was somewhere about 500 years before our era. Since that time there has been a continual progress in mathematics, truly, but think of the vast time during which the mind of man was a blank in this matter. Is there any wonder there are yet survivals of the old myth that lived so happily while ignorance reigned? Indeed it is only by keeping at high pressure all the time that we save ourselves from reverting to the old type holus-bolus; and even with all our laws and education and lofty examples, we still regard the sword as the final arbiter, must do so in fact, to save ourselves. What wonder then that the apparently simple conception of the flat Earth holds a place, connecting us directly with our ancestors prehistoric?

There is no denying that the E. F. is sincere. Whoever has met one must have have been assured of that. He is not like a child who, thinking at first the world is flat, has yet a mind receptive and capable of grasping the idea of a globe and of people living "with their heads down." The E. F. simply cannot grasp this;

arguments are useless. The particular part of the grey matter, the duty of which it is to treasure up this idea, is either absent or atrophied, probably the latter. Geometry is to him a name only; the name given to a network of lines drawn upon a black-board.

I would therefore regard our good friend of this persuasion as a modern specimen of old world man. Of course we have all a common descent, when we refer back far enough, but it is not given to every one to be imbued with the ideas of the pre-Pythagorean ages. As an avowed lover of everything antique, I will not be the one to press the E. F. too hard. Saying this however I do not mean to champion what may be called the "improved type." If we are to have a flat Earth let us have it straight, without any nonsense. We can stand that, but we do not want some long haired cross type to come along and tell us the Earth is neither flat nor round but that we are living in a hole! For one I positively will not stand that. Such a man would more than steal, he would rob a church (with no Pickwickian reservation). If driven hard to find a use for him we might perhaps turn him over to sup with the four-dimension space man who is striving to make a model. Two such fertile brains might evolve something by way of illustration.

No, I will have nothing to do with the man who lives in a hole, but for the genuine E. F. I trust always to have the kindest regards.

TORONTO.

PLANET NOTES FOR SEPTEMBER.

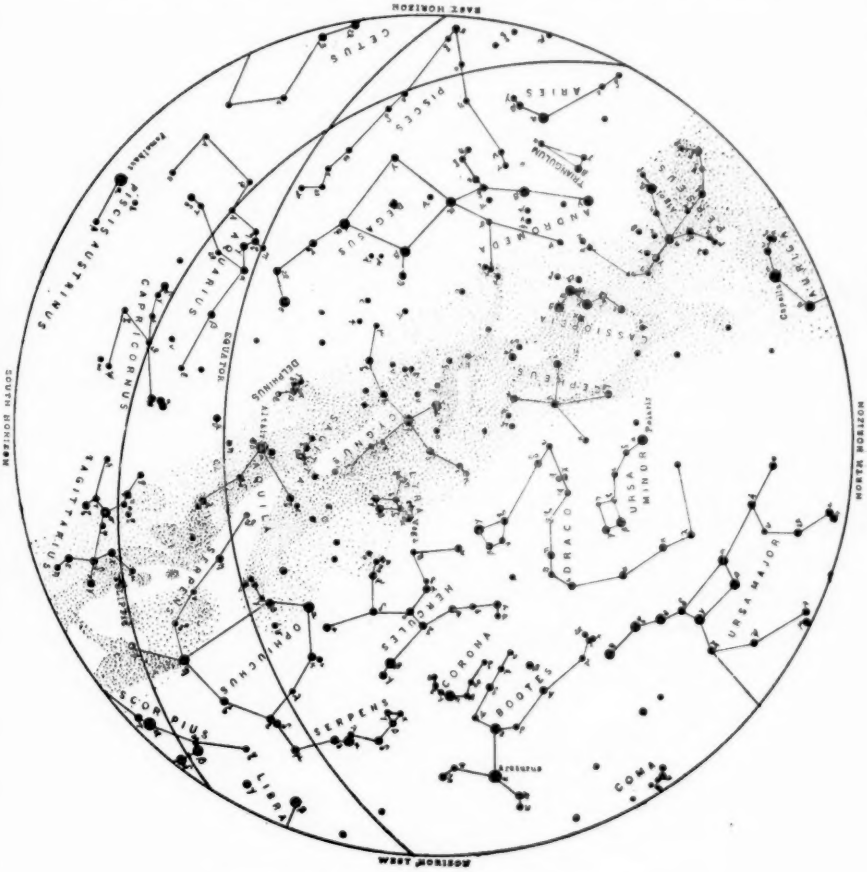
H. C. WILSON.

Mercury will be at inferior conjunction, *i.e.* between the Earth and the Sun, on Sept. 4, the planet will then be about 4° south of the Sun's center. On Sept. 21 Mercury will be at greatest elongation west from the Sun and will be visible as morning planet.

Venus will be at greatest elongation east from the Sun, 46° 32′, on the morning of Sept. 22. At that time just half her illuminated surface will be turned toward us and her phase will be like that of the Moon at first quarter. The planet is now moving so far to the south in declination that good views are very difficult to get in this latitude. The study of the surface markings is extremely tantalizing. At Northfield during August and the latter part of July we have had several days when the seeing was good; almost good enough to show the markings on Venus. At moments a whole network of markings would be revealed but not long enough for one to seize their configuration. At these moments the appearance was very much like that drawn by Schiaparelli several years ago. At no time did we glimpse anything that had the sharpness of outline indicated by the Flagstaff observers. Generally the unsteadiness of the image so masked all the markings as to leave only the vaguest kind of a shading on the disc of the planet.

Mars rises a little before midnight and comes to the meridian about seven

o'clock in the morning. Observations are possible from three to six o'clock. The diameter of the planet's disc increases from 7″ to 8″ during the month. In the June number of the *Monthly Notices* of the Royal Astronomical Society Mr. A. C. D. Crommelin gives an ephemeris for physical observations of Mars, following



THE CONSTELLATIONS AT 9 P. M., SEPTEMBER 1, 1898.

the same methods and using the same constants as the late Dr. Marth. From this we extract the following data:

P = the position angle of the axis of Mars.
L = the longitude of Earth reckoned from the Vernal Equinox of Mars.
B' = the latitude of Earth from Mars' equator.
B = the latitude of the Sun from Mars' equator.
ω = the longitude of the Central Meridian from the Zero Meridian on Mars.
T = time of passage of the Zero Meridian.
d = apparent diameter.
δ = defect of illumination.

Greenwich Noon.		*P* °	*L* °	*B'* °	*B* °	ω °	*T* h m		*d* ″	δ ″
Sept.	1	333.06	184.06	+ 3.22	— 14.11	83.13	12 18	A. M.	6.50	0.76
	3	333.66	185.17	3.73	13.71	63.83	1 38	"	6.56	0.77
	5	334.26	186.27	4.24	13.30	44.53	2 57	"	6.61	0.78
	7	334.87	187.37	4.75	12.89	25.24	4 17	"	6.66	0.79
	9	335.49	188.47	5.25	12.48	5.95	5 36	"	6.72	0.80
	11	336.11	189.55	5.73	12.07	346.67	6 55	"	6.78	0.81
	13	336.73	190.63	6.20	11.65	327.40	8 14	"	6.84	0.82
	15	337.36	191.70	6.67	11.23	308.14	9 35	"	6.90	0.83
	17	337.99	192.76	7.13	10.81	288.89	10 52	"	6.97	0.84
	19	338.63	193.81	7.59	10.39	269.65	12 11	P. M.	7.04	0.85
	21	339.27	194.86	8.03	9.97	250.42	1 30	"	7.12	0.86
	23	339.90	195.90	8.47	9.55	231.19	2 49	"	7.20	0.87
	25	340.52	196.93	8.90	9.12	211.97	4 8	"	7.27	0.89
	27	341.15	197.94	9.32	8.69	192.76	5 27	"	7.34	0.90
	29	341.78	198.94	+ 9.73	— 8.26	173.56	6 45	"	7.41	0.91

The planet's sidereal rotation in 24 hours is assumed to be 350°.89202. The winter solstice of Mars' northern hemisphere occurred May 31.7, 1898, and the spring equinox will occur Nov. 6.3, 1898.

Mars is the bright red star which you see toward the east after midnight, between the Hyades and Gemini.

Jupiter may yet be seen toward the south-west in the early evening but is too low for observation. Surely none of our readers failed to notice the conjunction of the brilliant planets Jupiter and Venus on the 18th of August. Especially on the 20th and 21st, when the crescent Moon was in the same portion of the sky, the sight of the three heavenly bodies was a beautiful one.

Saturn is almost too far west for useful observations but is still visible toward the south-west for a short time in the evening.

Uranus being near Saturn in Scorpio is seen under the same conditions.

Neptune is in Taurus a little way west of Mars and may be observed in the morning by those having sufficiently powerful telescopes. Neptune will be at quadrature, 90° west from the Sun, on the morning of Sept. 17.

The Moon.

		Phases.	Rises. (Central Standard time at Northfield; Local Time 13m less.) h m		Sets. h m	
Sept.	7	Last Quarter	10 18	P. M.	2 35	P. M.
	15	New Moon	5 33	A. M.	5 53	"
	22	First Quarter	1 40	P. M.	10 19	"
	29	Full Moon	5 26	"	7 3	A. M.

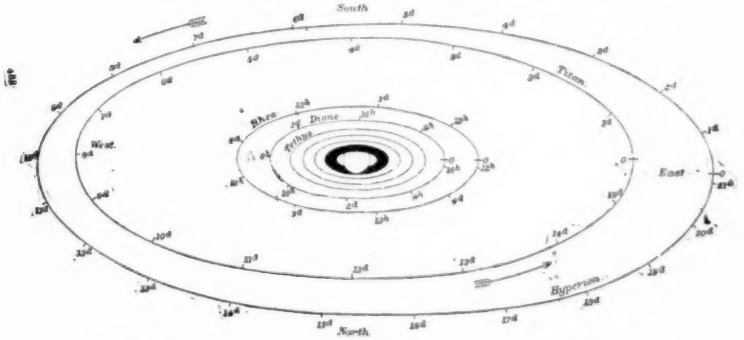
Occultations Visible at Washington.

Date 1898.	Star's Name.	Magnitude.	IMMERSION. Washington M. T. h m	Angle f'm N pt. °	EMERSION. Washington M. T. h m	Angle f'm N pt. °	Duration. h m
Sept. 4	μ Arietis	6.0	13 14	86	14 29	220	1 15
5	9 Tauri	7.0	14 34	45	15 52	275	1 18
6	62 Tauri	6.0	11 1	78	12 0	253	0 59
8	5 Geminorum	6 7	12 11	42	12 53	311	0 42
9	44 Geminorum	6.0	13 26	32	13 57	333	0 31
20	B.A.C. 5253	5.8	6 37	22	6 58	346	0 21
25	B.A.C. 7263	5.9	5 47	122	6 29	189	0 42
26	B.A.C. 7620	5.9	6 32	89	7 38	211	1 6
27	B.A.C. 7951	6 7	7 48	113	8 29	179	0 41
28	15 Piscium	6.6	5 48	109	6 29	194	0 41
28	19 Piscium	4.9	13 23	42	14 33	253	1 10

Saturn's Satellites.

[The diagram indicates the position of the outer satellites of Saturn at intervals of 1 day, after greatest eastern elongation. The ephemeris below gives the Central Standard times when the satellites will be at either eastern elongation (E) or western elongation (W), or, in the case of the outermost ones, inferior conjunction, south of the planet, (I) and superior conjunction, north of the planet, (S).]

APPARENT ORBITS OF THE SEVEN INNER SATELLITES OF SATURN, at opposition in 1898, as seen in an inverting telescope.



I. MIMAS.

Period $0^d\ 22^h.6$

	h		
Sept. 1	7.2	P. M.	E
2	5.8	"	E
8	8.9	"	W
9	7.5	"	W
10	6.1	"	W
17	7.9	"	E
18	6.4	"	E
25	8.1	"	W
26	6.7	"	W
27	5.3	"	W

II. ENCELADUS.

Period $1^d\ 8^h.9$

	h		
Sept. 2	7.4	P. M.	E
4	4.3	A. M.	E
5	1.2	P. M.	E
6	10.1	"	E
8	7.0	A. M.	E
9	3.9	P. M.	E
11	12.8	A. M.	E
12	9.7	"	E
13	6.6	P. M.	E
15	3.5	A. M.	E
16	12.4	P. M.	E
18	9.3	"	E
20	6.2	A. M.	E
21	3.1	P. M.	E
22	12.0	MIDN	E
23	8.9	P. M.	E
25	5.8	A. M.	E
26	2.7	P. M.	E
27	11.6	"	E
29	8.5	A. M.	E
30	5.4	P. M.	E

III. TETHYS.

Period $1^d\ 21^h.3$

	h		
Sept. 2	12.1	A. M.	E
3	9.5	P. M.	E
5	6.8	"	E
7	4.1	"	E
9	1.5	"	E
11	10.8	A. M.	E
13	8.1	"	E
15	5.4	"	E
17	2.7	"	E
19	12.1	"	E
20	9.4	P. M.	E
22	6.7	"	E
24	4.1	"	E
26	1.4	"	E
28	10.7	A. M.	E
30	8.1	"	E

IV. DIONE.

Period $2^d\ 17^h.7$

	h		
Sept. 1	5.3	A. M.	E
3	11.1	P. M.	E
6	4.8	"	E
9	10.5	A. M.	E
12	4.2	"	E
14	9.9	P. M.	E
17	3.6	"	E
20	9.3	A. M.	E
23	3.0	"	E
25	8.7	P. M.	E
28	2.4	"	E

V. RHEA.

Period $4^d\ 12^h.5$

	h		
Sept. 2	8.3	A. M.	E
6	8.8	P. M.	E
11	9.3	A. M.	E
15	9.8	P. M.	E
20	10.3	A. M.	E
24	10.8	P. M.	E
29	11.3	A. M.	E

VI. TITAN.

Period $15^d\ 23^h.3$

	h		
Sept. 3	10	P. M.	W
7	9	"	S
11	6	"	E
15	6	"	I
19	9	"	W
23	8	"	S
27	5	"	E

VII. HYPERION.

Period $21^d\ 7^h.6$

d		d	
Sept. 1.3	S	Sep. 17.5	W
7.2	E	22.8	S
12.6	I	28.7	E

VIII. JAPETUS.

Period $79^d\ 22^h.1$

Sept. 10.2 I Oct. 1.0 W

VARIABLE STARS.

J. A. PARKHURST.

Minima of the Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time.]

1898.

U CEPHEI.

	d	h
Oct.	5	17
	10	16
	15	16
	20	16
	25	15
	30	15

ALGOL.

	d	h
Oct.	2	13
	5	10
	8	7
	16	21
	19	18
	22	15
	25	12
	28	8

λ TAURI.

	d	h
Oct.	2	10
	6	9
	10	8
	14	7

Y CYGNI.

Even min.

Oct.	2	8

Odd min.

Oct.	3	12

R CANIS MAJORIS.

Every 8th min.

P = 1d 3.3h

	d	h
Oct.	7	21
	16	23
	26	1

W DELPHINI.

	d	h
Oct.	1	7
	20	13
	25	8

S CANCRI.

	d	h
Oct.	19	13

S VELORUM.

	d	h
Oct.	30	22

Maxima and Minima of Long Period Variables.

1898 November.

MAXIMA.

		m	day
62	S Sculptoris	6.5	11
294	W Cassiopeae	8 5	5:
401	U Sculptoris	8 3	26:
513	R Piscium	8	25
659	X Cassiopeae	9.5	8:
782	R Arietis	8	6
1386	T Eridani	7	5
2013	U Aurigae	8.5	5
2539	R Canis minoris	7.5	16
2742	S Geminorum	8.5	4
4225	X Centauri	8	10:
4407	R Corvi	7	29
4557	S Ursae Majoris	7.5	11
5070	Z Virginis	10	10
5830	R Scorpii	10	17
5831	S Scorpii	10	9
6044	S Herculis	6.5	13:
6512	T Herculis	7.5	17
6624	T Serpentis	10	5
6849	R Aquilae	6.5	23
6900	W Aquilae	7.5	12:
7266	RT Sagittarii	7.5	30
7404	R Microscopii	8	27
7907	U Aquarii	9.5	25:
7909	S Piscis Aust.	9	18
7999	X Aquarii	8.5	15

MINIMA.

		m	day
2100	U Orionis	< 12	13:
2583	L_2 Puppis	6	10
2857	U Puppis	< 14	—
3060	U Cancri	< 14	—
3184	T Hydrae	< 13	—
4816	V Virginis	< 13	—
4948	R Canum Ven.	11.5	—
5095	R Centauri	9	30
5430	T Librae	< 13	18
5504	S Coronae	12	8
5511	RS Librae	13	—
5776	X Scorpii	< 13	—
6682	X Ophiuchi	9	—
6894	S Lyrae	12	—
7118	X Aquilae	< 12	—
7120	χ Cygni	13.5	25
7260	Z Aquilae	11	—
7261	R Delphini	12	7:
7577	X Capricorni	< 16	—
7571	V Capricorni	14	—
7659	T Capricorni	13.5	18
8068	S Lacertae	< 12	19

Y CYGNI. The first minimum of each class is given. The others follow every third evening about five minutes earlier.

S LYRAE. The minimum magnitude is given in the above ephemeris as 12,

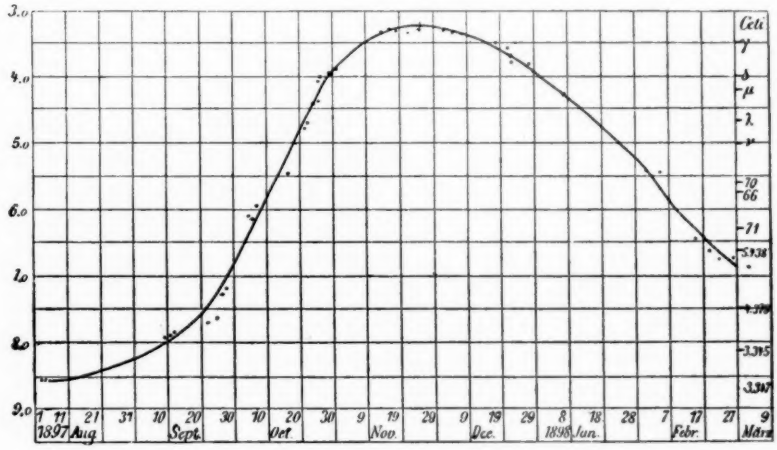
but later observations show that it becomes much fainter. It remained below 12.5 magnitude from September 1897 to February 1898. It is now 11.8 magnitude.

The minimum of 7118 X Aquilae is still three months away according to the above ephemeris, but the star is already 12.5 magnitude, so that a minimum magnitude between 13 and 14 will doubtless be reached.

NOTES.

SS CYGNI. Mr. Zaccheus Daniels has kindly sent me his observations of the past maximum, nine in number, also one by Mr. David Flanery. These with six of my own, cover the maximum thoroughly, only two days being missed while the star was above normal light. The rise began July 19, the maximum, at 8.5 magnitude, was passed July 21.8, and normal light was reached July 30.0. The star was above normal light 11 days, a little less than the typical "short" maximum. The interval since the last maximum was 60.6 days, exactly equal to the preceding interval. The preceding maximum was a "long" one, and was followed by a 43 day period of normal light, about the usual period following a "long" maximum.

MIRA. No. 3506 of the *Astronomische Nachrichten* contains two valuable articles on Mira. The first, by Professor W. Stratonoff, of Taschkent Observatory, gives the light curve from 13 observations, showing a maximum 1897 Jan. 5 at 3.60 magnitude; also a curve from 18 observations, with the resulting maximum 1897 Nov. 23, at 3.06 magnitude. The magnitudes of the comparison stars are taken from the Uranometria Oxoniensis. In regard to the secondary maxima and fluctuations in the light of Mira Professor Stratonoff says: "These are without doubt real phenomena and not inaccuracies in the observations."



The second article is by Dr. A. A. Nijland, of the Utrecht Observatory, and gives the magnitude results of 45 observations beginning 1897 Aug. 3, and ending 1898 March 2. The resulting light curve shows the maximum to have been passed Nov. 26 at 3.24 magnitude. On the margin of the figure (which is here reproduced) are shown in convenient position, the magnitudes of the comparison

stars. The interval since the last maximum is 319 days, as compared with 331.6 days, the mean interval given in the Third Catalogue. It is interesting to note that the platted points in Dr. Nijland's curve show a secondary maximum Dec. 20 in complete agreement with Professor Stratonoff's results.

In this connection it may be pointed out that the light curve of Mira given in the first edition of *Young's General Astronomy* page 483, is very misleading in character, if recent results can be trusted, especially so as this is taken as a type of the light changes of a large proportion of the variables. The error in this case is probably due to the fact that in any one season at least one quarter of the light curve is invisible on account of the star's proximity to the Sun. The new edition of this unrivalled work will probably contain a corrected curve.

VARIABLES STARS IN RECENT PUBLICATIONS. "*Das Weltgebäude*" by Dr. M. Wilhelm Meyer, (Leipsic and Vienna, 1898) contains an excellent chapter on new and variable stars. It is illustrated with numerous charts of the fields around interesting variables, light curves of the various classes, the spectrum of Nova Aurigae, and a thorough discussion of the different theories advanced to account for stellar varibility. The light curve of Mira is given in accordance with recent observations.

"*ATLAS DER HIMMELSKUNDE*" is the title of a splendidly illustrated folio publication edited by Armand Freiherr v. Schweiger-Lerchenfeld, aided by Dr. L. Weinek. The article on variable stars is illustrated by a double chart showing the positions of all variables known in 1895. It also contains a representation of the Andromeda nebula with the new star of 1885. A large reproduction of a photograph taken at the Lick Observatory shows the region surrounding Nova Aurigae.

YERKES OBSERVATORY, 1898, Aug. 13.

COMET NOTES.

Ephemeris of Perrine's Comet *b* 1898.

[From *Astronomische Nachrichten* No. 3504.]

		α			δ			log r	log Δ	Brightness
		h	m	s	°	′	″			
Sept.	1	6	28	31	+ 51	12	52	0.4282	0.4620	0.05
	2		29	4	51	11	9			
	3		29	35	51	9	30	0.4319	0.4615	0.05
	4		30	4	51	7	54			
	5		30	31	51	6	23			
	6		30	57	51	4	55			
	7		31	21	51	3	32	0.4392	0.4601	0.05
	8		31	42	51	2	12			
	9		32	2	51	0	57			
	10		32	19	50	59	45			
	11		32	34	50	58	37	0.4463	0.4584	0.05
	12		32	48	50	57	32			
	13		33	0	50	56	32			
	14		33	10	50	55	35			
	15		33	18	50	54	40	0.4533	0.4564	0.05
	16		33	23	50	53	49			
	17		33	26	50	53	1			
	18		33	27	50	52	17			
	19		33	27	50	51	35	0.4601	0.4542	0.05
	20	6	33	24	+ 50	50	56			

		α			δ			log r	log Δ	Brightness
		h	m	s	°	′	″			
Sept.	21	6	33	19	+ 50	50	19			
	22		33	11		50	49	45			
	23		33	2		50	49	13	0.4669	0.4518	0.04
	24		32	50		50	48	43			
	25		32	37		50	48	14			
	26		32	21		50	47	47			
	27		32	3		50	47	21	0.4735	0.4493	0.04
	28		31	42		50	46	56			
	29		31	20		50	46	32			
	30		30	55		50	46	9			
Oct.	1	6	30	28	+ 50	45	46	0.4800	0.4467	0.04

Elements of Giacobini's Comet *g* 1898.—This comet does not appear to have been very much observed. It is rapidly growing fainter because of its recession from the Earth and Sun. Elements depending upon observations eight and ten days apart have been computed by Hussey at Mt. Hamilton and Javelle at Nice.

ELEMENTS OF COMET *g* 1898.

	HUSSEY.				JAVELLE.			
T =	1898 July 25.84828 Gr. M. T.				July 24.894 Paris M. T.			
	°	′	″		°	″		
ω =	22	41	26.5	1898.0	21	54 6	1898.0	
Ω =	278	17	30.3		278	17.2		
i =	166	50	58.1		166	51.0		
log q =	0.175956				0.17734			

The latest ephemeris extends to August 26 on which the position of the comet was $\alpha = 13^h\ 37^m\ 34^s$, $\delta = -\ 2°\ 18'.6$ and the brightness less than one-fourth that at the time of discovery. According to Hussey's elements the constants for the equator of 1898.0 are

$$x = r\,[9.988706]\ \sin\,(v + 194°\ 10'\ 44''.0)$$
$$y = r\,[9.970315]\ \sin\,(v + 279\ \ 6\ 18\ .7)$$
$$z = r\,[9.625766]\ \sin\,(v + 313\ 53\ 58\ .2)$$

Ephemeris of Wolf's Comet.

[From *Astronomische Nachrichten* No. 3506.]

Berlin Midnight		α			δ		log r	log Δ	Brightness
		h	m	s	°	′			
Sept.	1	5	45	36	+ 12	10.0	0.23257	0.22957	
	2		47	46	+ 11	55.0			
	3		49	53	+ 11	39.8	0.23432	0.22714	2.6
	4		51	59	+ 11	24.3			
	5		54	5	+ 11	8.8	0.23610	0.22468	
	6		56	20	+ 10	53.0			
	7	5	58	12	+ 10	37.1	0.23792	0.22223	2.6
	8	6	0	12	+ 10	21.1			
	9		2	11	+ 10	4.9	0.23979	0.21979	
	10		4	10	+ 9	48.4			
	11		6	7	+ 9	31.8	0.24167	0.21733	2.6
	12		8	3	+ 9	15.2			
	13		9	56	+ 8	58.3	0.24360	0.21487	
	14		11	48	+ 8	41.3			
	15		13	38	+ 8	24.2	0.24558	0.21241	2.6
	16		15	28	+ 8	6.7			
	17	6	17	15	+ 7	49.1	0.24756	0.20994	

Berlin Midnight		α h	m	s	δ °	′	log r	log Δ	Brightness
Sept.	18	6	19	1	+ 7	31.7			
	19		20	45	+ 7	14.2	0.24958	0.20749	2.6
	20		22	28	+ 6	56.4			
	21		24	9	+ 6	38.5	0.25162	0.20502	
	22		25	48	+ 6	20.4			
	23		27	26	+ 6	2.2	0.25370	0.20257	2.6
	24		29	2	+ 5	43.9			
	25		30	37	+ 5	25.5	0.25580	0.20013	
	26		32	10	+ 5	7.0			
	27		33	41	+ 4	48.4	0.25791	0.19767	2.6
	28		35	10	+ 4	29.7			
	29		36	37	+ 4	11.0	0.26005	0.19524	
	30		38	3	+ 3	52.1			
Oct.	1	6	39	28	+ 3	33.2	0.26221	0.19280	2.7

GENERAL NOTES.

Our first plate is not new. It is used to show "canals" of Mars while the new views of our article are being considered. The plate is taken from Mr. Lowell's chart of Mars.

Philosophy of Hyperspace.—Professor Newcomb's paper on the philosophy of hyperspace in this number is a thoughtful production. It seems to us to show how the imagination can be used, in some ways, as a legitimate instrument of vigorous mathematical reasoning. His statement that all being may not necessarily be confined to space of three dimensions is food for the psychologist who can use mathematical concepts.

Focal Length of the Equatorial of Chamberlin Observatory.—Different statements of the focal length of the equatorial of the Chamberlin Observatory, at University Park, Colorado have been published. Director Howe says the clear aperture of this instrument is 20 inches, and that its focal length is 25 feet and 8 inches. Our report of this instrument in the table of telescopes in the July number was incorrect.

Conference of Astronomers and Physicists.—At the meeting of astronomers and physicists to be held at Cambridge, Mass., beginning Aug. 18, 1898, it is expected that the following papers will be presented: On an Effective Insulation of Mercurial Horizons. By Professor David P. Todd. On the Founding of Astronomical and other Instruments of Precision. By Professor David P. Todd. On a Practical Method of Photographing the Spectrum of the Corona in Numerous Distinct Regions. By Professor David P. Todd. Personal Equation in Transit Observations. By Professor Arthur Searle. The Zodiacal Light. By Professor Arthur Searle. On the Spectra of Stars of Secchi's Fourth Type. By Professor George E. Hale. On the K Lines of β Aurigae. By Miss A. C. Maury. Some Investigations relating to Zenith Telescope Latitudes. By Professor George C. Comstock. Classification of the Spectra of Variable Stars of Long Period. By Mrs. M. Fleming. Stars of the Fifth Type in the Magellanic Clouds. By Mrs. M. Fleming. Variable Stars in Clusters. By Professor Solon I. Bailey. Meridian Observations for Stellar Parallax. By Mr. Albert S. Flint. The Effect of Atmospheric Disturbance on Telescopic Definition. By Professor G. W. Hough. The

Observation of Occultations of Stars by the Moon, by Professor G. W. Hough. On the Spectra of Certain Nebulae, by Miss Agnes M. Clerke. The Variable Star U Pegasi, by Professor G. W. Myers. Some Remarks regarding the Parallax of 61^1 and 61^2 Cygni, by Professor H. S. Davis. The Probable Range of Temperature on the Moon, by Professor Frank W. Very. Rotation of the Asteroids, by Mr. Henry M. Parkhurst. Statement relating to the Work of the Flower Astronomical Observatory, by Professor C. L. Doolittle. A Brief Account of the Work of the Blue Hill Meteorological Observatory, by Mr. A. Lawrence Rotch. The Direct Grating Spectroscope and its Applications to Stellar Photography, by Professor Charles Lane Poor. An exhibition will be made including, among others, the following instruments: Zenith Sectors, Transit Instrument, and Quadrant used by Andrew Ellicott in the last century. The first Bond Chronograph. A New Form of Electrically controlled Chronograph, by Professor A. G. Webster. A Hough's Printing Chronograph made for the Philadelphia Observatory. Instrument for determining Periods of Periodic Variations.

Who Discovered Comet III 1862?—In your interesting and instructive articles on Comet Families, you have fallen into an error in ascribing the discovery of this comet to Tuttle. The subject was ventilated at the time of discovery but this was 36 years ago. A recital of the facts of its discovery may interest the readers of POPULAR ASTRONOMY and to them I leave the question whether its discovery belongs to him or to me.

At that time I was a subscriber to the New York Daily Times, and on July 15, 1862, I saw the statement that "a comet had been discovered north east of the north star moving very fast." I told the people of the village (Marathon, N. Y.) of its discovery, and that to-night I am going to try to find it. As soon as it was dark I took my comet-seeker to a neighbor's back yard and in less than five minutes I ran across a beautiful comet apparently north east of the north star, which I took for granted, as everybody would, that it was the comet I was searching for. The next morning I told the people of the village that I had found the new comet, and, that it is bright and has a short tail. In order to ascertain what astronomers meant by saying it is moving very fast, whether real or apparent, I took notice of its configuration with some of the bright stars in the field.

The next night I expected a long search for it, as the *Times* did not state in what direction it was moving, and a near-by barn obstructed much of my view in a northeast direction. Pointing the telescope the next night to the place of the comet on the previous evening, the comet was not seen, but was in a moment found near by, having moved but little, which surprised me, but still no suspicion was entertained that it was another comet. Some three or four days after the same paper announced that another comet was discovered northeast of the north star by Tuttle. No one can realize my surprise at the announcement. As Professor Hough, then director of the Dudley Observatory, was the only astronomer I was personally acquainted with, I stated the facts to him, giving from memory its configuration with stars in the field on the first night, and he decided that the diagram of the stars agreed with the place of the comet on the night of discovery. Of course no one could expect I would announce to the world the discovery of a comet already known. The statement of the case can be seen in "The Annual of Scientific Discovery" for that year. See also Chamber's Catalogue of Comets and their discoverers, where the discovery of this interesting comet is ascribed to me. See also a foot note saying discovered by Tuttle on July 18 and later by Simons, (not Simmons). The owner of the back yard is still living, and, also two men

who were working for me, to whom I told a new comet was discovered and that to-night I am going to find it and to whom I told the next morning I had found it.

Any way I am glad you have called the comet something, even if you did get the name wrong. It was one of the finest comets of the century, and had a tail 25° long. It is also a periodic of about 123 years, the elements of its orbit agreeing with those of the August 10th star shower, and although such an interesting one almost every astronomer in the world who has ever had occasion to speak of it simply call it Comet III 1862. Apropo to this is the little telescopic comet discovered by Tempel which is related to the great November star shower, yet every astronomer dignifies it as "Temple's Comet." So much for fame. LEWIS SWIFT.

LOWE OBSERVATORY, Echo Mountain, Cal.
Aug. 10, 1898.

Meteors Seen at Brainard Observatory.—The evening of August 9 although somewhat hazy, was still not sufficiently obscured to prevent shooting-stars brighter than the fourth magnitude. From 10 to 11 P. M., but very few were seen.

The evening of Aug. 10 was clear and fine. A careful watch, facing the radiant was kept from 10 to 11 P. M. 21 meteors were seen. Of these 8 were as bright or brighter than a first magnitude star, 18 were Perseids and 3 were "stragglers." Nearly all moved rapidly, mostly towards W or S, 6 left short-lived trails, 2 left trails which persisted for about 3 sec. There were three "pairs," one following another in very nearly the same path. All of the bright ones were golden colored. One, a very fine one, much brighter than Venus at its brightest, shot southwest through Cygnus at $10^h\ 52^m$ P. M., nearly in the zenith. It was pure white and left a trail lasting about one second.

The evening of Aug. 11 was somewhat hazy, yet all meteors brighter than the fourth or fifth magnitude could be seen. Between 10^h and 11^h P. M. a careful watch was maintained, facing the radiant; 9 were seen of which only 4 were Perseids. There was one "pair"; 2 were bright, leaving brief trails—both Perseids. One fine bright golden meteor passed southwest, near Vega, at $10^h\ 59^m$ P. M., leaving a long trail which disappeared in about two seconds.

Of the four "pairs" visible, counting both evenings, three passed westwards not very far distant (within 6° or 8°) above or below Polaris. Is there a segregated stream of meteors towards one border, or within the limits of the path of the Perseids?

I thought perhaps you would be interested, and so send you this account. Circumstances prevented a long continued watch, but much care was exercised throughout the hour each evening. A. E. BRAINARD.

Watertown, N. Y.
August 12, 1898.

The Supposed Variable Star, Y Aquilae.—Measures to determine the light curves of variable stars of short period, north of declination −40° are now in progress with the meridian photometer. Four sets of four settings each are ordinarily made when the star to be observed is about half an hour east of the meridian, and again about an hour later. These measures are repeated on twenty or thirty nights. The principal error is that due to the unequal transparency of the air in different portions of the sky, the stars compared being often far apart. The accidental errors of measurement are small owing to the number of settings. Smooth light curves have been found for all the stars thus measured, with the exception of + 10° 3787. The designation Y Aquilae was given to this star by Mr.

S. C. Chandler, and in his catalogue of variable stars he states that it varies from magnitude 5.3 to 5.7 in a period of 4.986 days. Also, that it was "Susp. by Gould, confirmed by Chandler, 1894; also by Yendell." It will be noticed that the period is so nearly five days, that for several months the same phase will recur at about the same hour angle, thus permitting errors to occur in visual observations by Argelander's method, such as are mentioned in Circular No. 23, and which led to such wholly erroneous conclusions in the case of U Pegasi.

The star + 10° 3787 was observed with the meridian photometer on nineteen nights, from August 25 to October 13, 1897. Placing together the observations having the same phase we find, corresponding to the phases $0^d.0$, $1^d.0$, $2^d.0$, $3^d.0$ and $4^d.0$ the mean residuals — 0.09, 0.00, + 0.02, + 0 02 and + 0.03. We might infer a variation with a range of a tenth of a magnitude, but the first value, — 0.09, depends on observations on a single night, and the range of the other four is only 0.03. This star is No. 39, of the standards selected by the observers at Potsdam, and they state that from their observations, they find no confirmation of the variation suspected by Dr. Gould. Mr. Chandler, however (Astron. Journ. XIV, 135) states that these observations, 57 in number, confirm the period of variation that he has found, although indicating that the range of variation is less. A reduction of these observations made here, however, leads to the same conclusion as that found at Potsdam. The actual number of observations of this star made at Potsdam appears to be 75, not 57, 49 of them in determining the light of the standards, and 26 in the supplementary zones. Grouping them according to a phase, we obtain the residuals — 0.07, — 0.02, + 0.01, 0.00 and — 0.16, corresponding to the phases $0^d.6$, $1^d.6$, $2^d.6$, $3^d.6$ and $4^d.6$. The last residual is reduced to — 0.12 if we reject the observations on one night, and to —0.09, if we reject those made on two nights and use only the observations from which the light of the fundamental stars was determined. To decide whether such residuals as these are due to accident, the Potsdam observations were again grouped assuming a period of six days instead of five. The mean residuals corresponding to the phases 0, 1, 2, 3, 4 and 5 days then become — 0.03, — 0.19, — 0.14, — 0.02, + 0.01 and 0.00. The preponderance of negative residuals is caused by the supplementary observations which indicate that the star was slightly brighter than when the standards were originally measured. Grouping the observations with the meridian photometer in the same way, we obtain the mean residuals 0.00, 0.00, — 0.07, — 0.02, — 0.02 and + 0.07. In both cases, therefore, a period taken at random indicates variability more clearly than that hitherto assumed. Mr. Yendell (Astron. Journ. XIV, 160), confirms visually the variability of this star.

The accuracy of the observations described in Circulars Nos. 23 and 25, seems to afford a conclusive test of the variability of this star. Accordingly, comparisons were made by Mr. Wendell with the photometer attached to the 15-inch equatorial telescope on May 9, 10, 13, 14, 21 and 22, 1898. Eighty settings were made each night. The comparison star was + 10° 3784. The mean differences of magnitude were 3.63, 3.64, 3.66, 3.66, 3.66 and 3.62, and the average deviations from their means, of the five groups of sixteen settings each on the different nights, were ± 0.022, ± 0.028, ± 0.020, ± 0.012, ± 0.030 and ± 0.012. The first and fourth nights have nearly the same phase, $0^d.8$. Combining these in one group, and placing the others in the order of phase, we have the phases, $0^d.8$, $1^d.8$, $2^d.8$, $3^d.9$ and $4^d.8$, and the corresponding residuals, 0.00, 0.00, — 0.02, + 0.02 and — 0.02. A positive residual, as usual, denotes that the star was faint. The average value of these residuals is ± 0.012 and the range 0.04.

The three series of photometric observations discussed above, therefore fail to

show any evidence of variation, since deviations of a tenth of a magnitude, except in the last series of measures, may be ascribed to errors of observation. Since it is impossible to prove that the light of a star never changes, this star may still be an Algol variable with a short time of variation, or the period may be entirely wrong.

EDWARD C. PICKERING.

HARVARD COLLEGE OBSERVATORY, Circular No. 30.

The Large Refractors of the World.—[Continued from page 311.] In the fourth column, with heading "Maker," the name of the firm who made the object-glass is given; in such cases as it is known that the mounting was made by a second firm, a number is affixed signifying respectively: (1) Warner and Swasey; (2) Gautier; (3) Repsold; (4) Ransomes and Sims; (5) Saegmuller.

Aperture in inches.	Focal Length.	Institution.	Maker.	Date of Erection.	Remarks.
13.0	135.1 in.	National Obs'y, Paris.	Henry Bros (2).	1889	The first seventeen telescopes in
13.0	"	National Obs'y, Bordeaux.	Henry Bros. (2).	1889	the list are those in use for the
13.0	"	University Obs'y, Oxford.	Sir H. Grubb.	1889	making of the Astrographic
13.0	"	Tacubaya Obs'y, Mexico.	Sir H. Grubb.	1889	Chart. The aperture and focal
13.0	"	National Obs'y, Toulouse.	Henry Bros. (2).	1890	length of these are practically
13.0	"	National Obs'y, Algiers.	Henry Bros. (2).	1890	identical.
13.0	"	Vatican Obs'y, Rome.	Henry Bros. (2).	1890	
13.0	"	Royal Obs'y, Greenwich.	Sir H. Grubb.	1890	
13.0	"	Melbourne Obs'y, Victoria.	Sir H. Grubb.	1890	
13.0	"	Sydney Obs'y, New South Wales.	Sir H. Grubb.	1890	
13.0	"	Royal Obs'y, Cape of Good Hope.	Sir H. Grubb.	1890	
13.0	"	National Obs'y, La Plata.	Henry Bros. (2).	1891	
13.0	"	San Fernando Obs'y, Spain.	Henry Bros. (2).	1891	
13.0	"	Catania Obs'y, Etna.	Steinheil.	1892	Mounted by Salmoiraghi.
13.0	"	Imperial Obs'y, Potsdam.	Steinheil (3).		
13.0	"	National Obs'y, Rio de Janeiro.	Henry Bros. (2).	1895	
13.0	"	The Obs'y, Helsingfors.	Henry Bros. (3).	1895	
13.0	.....	Queen's College, Cork.	Sir H. Grubb.	1891	
13.0	.....	Temple Obs'y, Taschkent.	Henry Bros. (2).		
13.0	16.9 ft.	Imperial Obs'y, Poulkova, Russia.	Henry Bros. (3).	1895	
13.0	135.1 in.	Perth Obs'y, West Australia.	Sir H. Grubb.	1897	
13.0	16.9 ft.	Royal Obs'y, Leyden.	Henry Bros. (2).	1894	Photographic.
13.0	16.0 "	Harvard Coll. Obs'y, Cambridge.	.....	....	Boyden Photographic.
13.0	15.2 "	Dudley Obs'y, Albany, N. Y.	Fitz.	1863	Visual.
12.8	17.8 "	Royal Obs'y, Greenwich.	Merz (4).	1860	At present used as guiding tele-
12.6	.....	Dr. Cruls, Rio de Janeiro.	T. Cooke & Sons	1894	[scope for 26-inch.
12.5	.....	Ann Arbor, Mich., U. S. A.	Fitz.		
12.5	.....	University Obs'y, Cambridge.	T. Cooke & Sons	1897	New Triplet.
12.3	.....	Vassar College, New York.	Alvan Clark.	....	Visual.
12.3	17.0 ft.	Morrison Obs'y, Missouri, U. S. A.	Alvan Clark.	1875	Visual.
12.2	17.0 "	National Obs'y, Paris.	Secretan.	....	Visual. Mounted by Eichens.
12.2	14.7 "	Oxford.	Sir H. Grubb.	1875	Visual.
12.2	15.0 "	Dudley Obs'y, Albany, N. Y.	Brashear (1).	1893	Visual. } By changing flint
12.0	13.5 "	Dudley Obs'y, Albany, N. Y.	Brashear (1).	1893	Photographic. } lens.
12.0	12.0 "	Baron v. Engelhardt, Dresden.	Sir H. Grubb.	1879	Visual.
12.0	.....	The Obs'y, Lyons.	Henry Bros.	....	Visual. Coude.
12.0	.....	McClean's Obs'y, Tunbridge Wells	Sir H. Grubb.	1884	Visual.
12.0	.....	Yerkes Obs'y, Wisconsin, U. S. A.	Brashear (1).	1891	Visual. Formerly at Kenwood.
12.0	.....	Middleton Univ. Obs'y, Conn.	Alvan Clark (5).	1868	
12.0	.....	S. V. White's Obs'y, Brooklyn.	Alvan Clark (5).	1870	
12.0	.....	Lick Obs'y, California, U. S. A.	Alvan Clark.	1881	Visual. Formerly Dr. Draper's.
12.0	.....	Military Academy, West Point.	Alvan Clark (5).		
12.0	.....	Naval Obs'y, Washington.	Alvan Clark.	1892	
12.0	.....	University of Illinois, Ill., U. S. A.	Brashear (1).	1896	
12.0	.....	Emerson McMillan Obs'y, Ohio.	Brashear (1).	1895	
12.0	.....	Smith College, Massachusetts.	Davis (1).	1887	
12.0	.....	Lowell Obs'y, Mexico.	Alvan Clark.	1894	
12.0	.....	Cordoba Obs'y, Argentina.	Alvan Clark (1).	1889	
12.0	.....	Protestant College, Beyrout, Syria.	Brashear (1).	1893	
12.0	.....	Mr. Barclay's Obs'y, Leytonstone.	T. Cooke & Sons	1865	
12.0	.....	Rev. J. Dunne Parker's Obs'y, Stevenage.	T. Cooke & Sons	1886	
12.0	19.0 ft.	Dublin University Obs'y, Dunsink.	Cauchoix.	....	Mounted by Grubb.
12.0	.....	Imperial Obs'y, Vienna.	Alvan Clark.		

Jupiter 1896-7.—We have just received the sixth annual report of Rev. W. R. Waugh, director of the Jupiter section of the British Astronomical Association. It contains a general account of the disk observations of the planet, a detailed description of the drawings reproduced, papers of interest on the Jovian features, satellite observations and a condensed summary of the work with some deductions therefrom. Mr. Waugh speaks of the equatorial zone of the planet as having more interest than in past years. Its color is of a "ruby-tinged golden hue," beautiful to behold. The transverse bands and wisps have been plainly seen. It is said that one observer has been very successful in discovering them, and in answer to the question what they are, ventures the suggestion that "they are not openings in the higher, level whitish cloudy matter, because their attenuated thread-like form seem to indicate that they overlie all we can see. The fact that they join with spots on the equatorial edges of the two belts seems to show the attractive influences in these belts extending over a space of 10,000 miles."

The altitude of these long and narrow clouds has been a point of interest to us for years. The fainter ones are sometimes certainly higher than the level of the Great Red Spot, for they have been seen to move over it. There are records of cloud-veiling over the Red Spot that are not narrow, but so far as we know they appear to be attenuated masses and lighter in color than other parts of the belts near them.

The Great Red Spot has not lost its interest, though it has decayed to the limit of visibility. A few English observers have been partially successful in seeing it, though the time is not far distant when observation will cease on account of its faintness if it goes on diminishing as in the past. One peculiarity about it has attracted the attention of several observers, viz:—that the spot is more plainly visible when near the preceding limb, than in other places on the planet's disk. Mr. Maw suggests that the reason for this may be that the following end of the spot is possibly of higher elevation than the preceding end, and presumably more steep, and hence more prominent when so observed. Many drawings show that the Great Spot is more plainly seen while on and near the preceding limb of the planet. What is this Great Red Spot? If it is a kind of plateau raised above the surface of the planet, and its loss of pinkish color is due to the abundance of cloud-like vapors which hide it from view, these vapors may disperse after a a while and the spot appear again in its full color. There have been some changes in its color since 1878, that brings to mind such a suggestion as this, as a possible cause of the irregular variation of the color of this curious Jovian object. If this supposed plateau be an eruptive condition on the planet's surface and has been gradually fading out because volcanic energy has ceased, then we may never see more of this interesting feature. It seems to us that the latter suggestion is the least probable of the two. The change of color, the almost permanent character of the spot, and the slow variations in all of its phases lead us to look for some other explanation; possibly the first will best satisfy trustworthy observations.

The spots on the borders and surfaces of the equatorial belts have received careful attention. At the recent apparitions, they have been usual in size, density and brightness, the dark spots probably predominating. They have appeared in every variety of form, though rarely circular. The director touches an important matter when he suggests that observers should make a study of the drift of these spots. It is very useful to know if all are subject to drift; if so in what way. Some good observations have been made already, but we need more. The prevailing theory of the origin of these spots is from volcanic activity following the analogy of the solar surface based on the supposition that Jupiter is a semi-sun.

Mr. Waugh presents lithographic copies of 18 drawings of Jupiter in connection with this report which were made by the aid of telescopes ranging from 5 to 12 inches clear aperture. The drawings were made during the first four months in 1897. The report is an excellent one and we give it permanent place in our library.

The Sun, 1896.—The report of Miss E. Brown, director of the section for the observation of the Sun of the British Astronomical Association has been received. It is the sixth in the series, so far, and is similar in make up to those preceding. It contains a daily record of the more important groups of Sun-spots, with paragraph summaries of lesser ones. Again and again small groups of spots have appeared between the larger ones, which is claimed to be a distinct sign of the decrease in solar activity. Especial notice has been given to the width of the penumbra of regular spots near the east or the west limb, for the purpose of gathering data that shall bear on the question of the level of the Sun-spots. Doubtless most, if not all of our readers, know that some discussion has been going on, in scientific papers during the last twelve months, regarding the central part of Sun-spots, some claiming that they are elevations above the general level of the solar surface, others contending that they are depression according to the generally accepted view. Those who desire to read the papers of observers and physicists relating to this subject will be interested in Father Cortie's article in the *Monthly Notices* and Professor Frost's paper in the *Astrophysical Journal.*

The number of groups of Sun-spots recorded for 1896 is 161 against 234 in 1895. The details of this report show good work and is a credit to the director and to the association.

Visibility of the Rœntgen Rays.—That the light effect of the Rœntgen rays is not due to an act of "accommodation" as has been alleged, has been proved by E. Dorn, with the aid of a medical friend, who intentionally paralyzed the accommodation capacity of one of his eyes with homatropine, and found the visual effect as strong as before. The fact that a straight rod sometimes casts a bent shadow into the eye, is explained by considering that the Rœntgen rays are not refracted by the beems of the eye. The rods therefore cast straight lines in the retina, which are ordinarily only produced by bodies bent in a certain manner. The straight lines are therefore interpreted as being due to bent rods.—*Electric Review, Aug. 17, '98.*

Very Like Prophecy.—About the year 1840 Thomas Dick, LL. D., an English writer on astronomical and other subjects, published a work entitled The Practical Astronomer. A chapter was devoted to a description of the camera and an account of the then but recently discovered daguerreotype process. Of the possibilities of the process Dr. Dick wrote thus:

"It is not impossible that this art, when it approximates perfection, may enable us to take representations of the sublime objects in the heavens. The sun affords sufficient light for this purpose and there appears no insurmountable obstacle to taking, in this way, a highly magnified picture of that luminary which shall be capable of being again magnified by a powerful microscope. It is by no means improbable, from experiments that have hitherto been made, that we may obtain an accurate delineation of the lunar world from the Moon herself. The plated disks prepared by Daguerre receive impressions from the lunar rays to such an extent as permits the hope that photographic charts of the Moon may be soon obtained; and, if so, they will excel in accuracy all the delineations

of this orb that have hitherto been obtained; and if they should bear a microscopic power, objects may be perceived on the lunar surface which have hitherto been invisible. Nor is it impossible that the planets Venus, Mars, Jupiter and Saturn may be delineated in this way, and objects discovered which cannot be discerned by means of the telescope. It might, perhaps be considered as beyond the bounds of probability to expect that even distant nebulæ might be fixed and a delineation of those objects produced which shall be capable of being magnified by microscopes; but we ought to consider that the art is only in its infancy, that plates of a more delicate nature than those hitherto used may yet be prepared, and that other properties of light may yet be discovered which shall facilitate such designs."

This certainly reads very like prophecy. Yet Dr. Dick was not a prophet nor the son of a prophet. He was simply one who was not only fully up to his times, as his writings show, but who was ahead of his times as the passage quoted and many others that might be cited abundantly prove. He was a delightful writer and his works must have done much to popularize astronomy. Not, in his case, was the good that he did "interred with his bones." One of his greatest services to astronomy was rendered long after he was dead and gone when a perusal of the very volume from which I have quoted started Professor E. E. Barnard on his astronomical career. For a knowledge of this fact I am indebted to POPULAR ASTRONOMY, Vol. I, Page 193.

Here the reflection, how curiously, how strangely things come about, forces itself. As in this instance. An English philosopher, quietly writing in his study, pens words which determine the career, in another hemisphere, of a young man then unborn, and, after half a century, result in the discovery of Jupiter's fifth satellite. The result is perfectly natural and legitimate but who could have foreseen, who would have dreamed that it would follow. R. M. MCCREARY.

Greensburg, Pa.

Historical Note About Wm. Bond & Son, Chronometer Makers.— The well known firm of Wm. Bond & Son is the only manufacturer of Chronometers in New England, and is the oldest firm in that business in the country.

The family were for generations prominent watch and clock makers in England prior to 1788, when Wm. Bond established himself here, about the time of Washington's inauguration; the present Mr. Wm. C. Bond being the fourth generation in America.

From the very beginning the members of this firm have been largely identified with the improvement and development of horology in America; they were the first importers of Marine Chronometers soon after their invention in England, and in 1812 Mr. Wm. C. Bond, the son of Wm. Bond, and afterwards the first director of the celebrated Observatory of Harvard College, made with his own hands the first chronometer ever produced in this country. The addition of chronometer balances to watches was due to the suggestion of Mr. Bond to his correspondents in London, and the firm imported the first chronometer watches made.

Mr. Richard F. Bond, the son of the latter, continued the work by important inventions in clocks and scientific instruments, and since his death the reputation of the firm is still sustained, for in 1870 after two years of experiment, they succeeded in successfully applying to chronometers an electric Break Circuit, for sending time signals, which attachment is one of the most important additions made to horological instruments for scientific use since the invention of the chronometer itself.

The wide reputation of the firm is shown by the fact that their instruments are in use in many of the principal Observatories of the Old World, as well as in this country, and also by the various departments of the U. S. Government.

See advertisement.

Errata.—In the paper on Ephemerides of Satellites, page 172, 10th line from the bottom, for *KEQ* read *EKQ* and 6th line from bottom, for *EKQ* read *KEQ*. In the computation of the place of Deimos for 1899 Jan'y 18, the aberration time was purposely left out. J. M.

Thos. P. Nichols, Publisher. The Printing and Publishing business of Thos. P. Nichols was established in 1850. The establishment has become widely known in all directions for the excellence of its product.

He is assisted in the business by his two sons, Frank H. and Fred. H., both practical printers in every detail, each working his way up from a boy in the office, through all branches.

The printing and publishing of mathematical, astronomical, and scientific works, receive best of care and attention, has given the office a name second to none in the country.

Among the late works issued from the Nichols Press in the astronomical line, have been, "Researches on the Evolution of the Stellar Systems" by Dr. T. J. J. See, of the Lowell Observatory, Flagstaff, Arizona. This book is quarto size and contains 266 pages Illustrated.

The late Dr. Benjamin Apthorp Gould's last work, entitled "Cordoba Photographs; Photographic Observations of Stellar Clusters from Impressions Made at the Argentine National Observatory" was also issued from this press. This work comprises 37 chapters with 50 pages introductory matter, and contains 544 quarto pages, printed in two columns—Spanish and English—but is made up largely of tabular matter. Thirty-seven charts for the corresponding chapters illustrate the volume. This work will be a standard book of reference, being placed in the principal astronomical observatories of the world, as well as with the foremost astronomers.

The *Astronomical Journal* is printed at the above office three times a month. This publication was founded by Dr. Gould in 1894, and with one exception (*Astronomische Nachrichten* a German publication), stands alone in its particular field. It is now edited by Dr. Chandler, of Cambridge, assisted by Professor Lewis Boss and Professor Asaph Hall.

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